



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup>:</b> <b>B32B 5/16, A61F 13/15</b>	<b>A2</b>	<b>(11) International Publication Number:</b> <b>WO 00/27625</b> <b>(43) International Publication Date:</b> 18 May 2000 (18.05.00)
<b>(21) International Application Number:</b> PCT/US99/26560 <b>(22) International Filing Date:</b> 10 November 1999 (10.11.99)  <b>(30) Priority Data:</b> 60/107,998                      11 November 1998 (11.11.98)    US 60/155,464                      21 September 1999 (21.09.99)    US  <b>(63) Related by Continuation (CON) or Continuation-in-Part (CIP) to Earlier Applications</b> US                                      60/107,998 (CIP) Filed on                                11 November 1998 (11.11.98) US                                      60/155,464 (CIP) Filed on                                21 September 1999 (21.09.99)  <b>(71) Applicant (for all designated States except US):</b> WEYER-HAEUSER COMPANY [US/US]; 33663 Weyerhaeuser Way South, Federal Way, WA 98003 (US).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> GRAEF, Peter, A. [US/US]; 13712 - 116th Street, Court East, Puyallup, WA 98374 (US). HOWARD, Fred, B. [US/US]; 15050 Starr Road East, Olalla, WA 98359 (US). MILLER, Charles, E. [US/US]; 22625 - 102nd Place SE, Kent, WA 98031 (US).		BOLSTAD, Clifford, R. [US/US]; 1938 S. 370th Court, Federal Way, WA 98003 (US). COLIN, Elston [GB/US]; 7307 Artondale Drive NW, Gig Harbor, WA 98335 (US). MARSH, David, G. [US/US]; 505 S.W. 335th Street, Federal Way, WA 98003 (US). EDMARK, Richard, A. [US/US]; 2245 East Crescent Drive, Seattle, WA 98112 (US). LI, Yong [US/US]; 3803 NE 45th Avenue, Tacoma, WA 98422 (US).  <b>(74) Agent:</b> RENZONI, George, E.; Christensen O'Connor Johnson & Kindness PLLC, Suite 2800, 1420 Fifth Avenue, Seattle, WA 98101 (US).  <b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>Without international search report and to be republished upon receipt of that report.</i>
<b>(54) Title:</b> RETICULATED ABSORBENT COMPOSITE  <div data-bbox="344 1205 1175 1499" data-label="Image"> </div> <b>(57) Abstract</b> <p>An absorbent composite having a reticulated core and a fibrous stratum is disclosed. The core and stratum are integrally formed, and the stratum is coextensive with an outward surface of the core. In one embodiment, the composite includes strata on opposing outward facing surfaces of the core. The core includes a fibrous matrix and absorbent material. The fibrous matrix defines voids and passages between the voids, which are distributed throughout the composite. Absorbent material is located within some of the voids. On wetting, absorbent material located in these voids is expandable into the void. Absorbent articles that include the composite are also disclosed.</p>		

## RETICULATED ABSORBENT COMPOSITE

### Field of the Invention

The present invention relates to an absorbent composite and more particularly, to a reticulated absorbent composite that includes superabsorbent material in a fibrous matrix.

### Background of the Invention

Cellulose fibers derived from wood pulp are used in a variety of absorbent articles, for example, diapers, incontinence products, and feminine hygiene products. It is desirable for the absorbent articles to have a high absorbent capacity for liquid as well as to have good dry and wet strength characteristics for durability in use and effective fluid management. The absorbent capacity of articles made from cellulose fibers is often enhanced by the addition of superabsorbent materials, such as superabsorbent polymers. Superabsorbent polymers known in the art have the capability to absorb liquids in quantities from 5 to 100 times or more their weight. Thus, the presence of superabsorbent polymers greatly increases the liquid holding capacity of absorbent articles made from cellulose.

Because superabsorbent polymers absorb liquid and swell upon contact with liquid, superabsorbent polymers have heretofore been incorporated primarily in cellulose mats that are produced by the conventional dry, air-laid methods. Wetlaid processes for forming cellulose mats have not been used commercially because superabsorbent polymers tend to absorb liquid and swell during formation of the absorbent mats, thus requiring significant energy for their complete drying.

Cellulose structures formed by the wetlaid process typically exhibit certain properties that are superior to those of an air-laid structure. The integrity, fluid distribution, and the wicking characteristics of wetlaid cellulosic structures are superior to those of air-laid structures. Attempts to combine the advantages of wetlaid composites with the high absorbent capacity of superabsorbent materials has led to the formation of various wetlaid absorbent composites that include superabsorbent materials. Generally, these structures include superabsorbent materials distributed as a layer within a multilayered composite. In these structures the superabsorbent polymer is relatively localized and not uniformly distributed throughout the absorbent structure and thus renders these composites susceptible to gel blocking. Upon liquid absorption, superabsorbent materials tend to coalesce and form a gelatinous mass that prevents the wicking of liquid to unwetted portions of the composite. By preventing distribution of acquired liquid from a composite's unwetted portions, gel blocking precludes the effective and efficient use of superabsorbent

materials in fibrous composites. The diminished capacity of such fibrous composites results from narrowing of capillary acquisition and distribution channels that accompanies superabsorbent material swelling. The diminution of absorbent capacity and concomitant loss of capillary distribution channels for conventional absorbent  
5 cores that include superabsorbent material are manifested by decreased liquid acquisition rates and far from ideal liquid distribution on successive liquid insults.

Accordingly, there exists a need for an absorbent composite that includes superabsorbent material and that effectively acquires and wicks liquid throughout the composite and distributes the acquired liquid to absorbent material where the liquid is  
10 efficiently absorbed and retained without gel blocking. A need also exists for an absorbent composite that continues to acquire and distribute liquid throughout the composite on successive liquid insults. In addition, there exists a need for an absorbent composition containing superabsorbent materials that exhibits the advantages associated with wetlaid composites including wet strength, absorbent  
15 capacity and acquisition, liquid distribution, softness, and resilience. The present invention seeks to fulfill these needs and provides further related advantages.

#### Summary of the Invention

The present invention relates to a reticulated fibrous absorbent composite containing absorbent material. The absorbent composite is a fibrous matrix that  
20 includes absorbent material and a three-dimensional network of channels or capillaries. The composite's reticulated nature enhances liquid distribution, acquisition, and wicking, while the absorbent material provides high absorbent capacity. Wet strength agents can be incorporated into the composite to provide wet integrity and also to assist in securing the absorbent material in the composite.

25 The absorbent composite formed in accordance with the present invention includes a stable three-dimensional network of fibers and channels that afford rapid acquisition and wicking of liquid. The fibers and channels distribute the acquired liquid throughout the composite and direct liquid to absorbent material present in the composite where the liquid is ultimately absorbed. The composite maintains its  
30 integrity before, during, and after liquid is introduced. In one embodiment, the composite is a densified composite that can recover its original volume on wetting.

In one aspect, the present invention provides an absorbent composite having a fibrous matrix that includes absorbent material. The fibrous matrix defines voids and passages between the voids, which are distributed throughout the composite.  
35 Absorbent material is located within some of the voids. The absorbent material located in these voids is expandable into the void.

In one embodiment, the reticulated absorbent composite includes at least one fibrous stratum. For such an embodiment, the composite includes a reticulated core and a fibrous stratum adjacent and coextensive with an outward facing surface of the core. In another embodiment, the composite includes strata on opposing outward facing surfaces of the core. The composite's strata can be composed of any suitable  
5 fiber or combination of fibers and can be formed from fibers that are the same as or different from the fibers used for forming the reticulated core.

In other aspects of the invention, methods for forming the composite and absorbent articles that include the composite are provided. The absorbent articles  
10 include consumer absorbent products such as diapers, feminine care products, and adult incontinence products.

#### Brief Description of the Drawings

The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated by reference to the following detailed  
15 description, when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a cross-sectional view of a portion of a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 2 is a photomicrograph of a cross section of a representative reticulated absorbent composite formed by a wetlaid method in accordance with the  
20 present invention at 12 times magnification;

FIGURE 3 is a photomicrograph of the wetlaid composite of FIGURE 2 at 40 times magnification;

FIGURE 4 is a photomicrograph of a cross section of a representative reticulated absorbent composite formed by a foam method in accordance with the  
25 present invention at 12 times magnification;

FIGURE 5 is a photomicrograph of the foam-formed composite of FIGURE 4 at 40 times magnification;

FIGURE 6 is a photomicrograph of a cross section of a representative reticulated absorbent composite formed by a wetlaid method in accordance with the  
30 present invention in a wetted state at 8 times magnification;

FIGURE 7 is a photomicrograph of the wetlaid composite of FIGURE 6 at 12 times magnification;

FIGURE 8 is a photomicrograph of a cross section of a representative reticulated absorbent composite formed by a foam method in accordance with the  
35 present invention in a wetted state at 8 times magnification;

FIGURE 9 is a photomicrograph of the foam-formed composite of FIGURE 8 at 12 times magnification;

FIGURE 10 is a cross-sectional view of a portion of an absorbent construct incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 11 is a cross-sectional view of a portion of another absorbent construct incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURES 12A and 12B are cross-sectional views of portions of an absorbent article incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 13 is a cross-sectional view of a portion of another absorbent article incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 14 is a cross-sectional view of a portion of another absorbent article incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 15 is a cross-sectional view of a portion of an absorbent construct incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 16 is a cross-sectional view of a portion of another absorbent construct incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 17 is a cross-sectional view of a portion of another absorbent construct incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 18 is a cross-sectional view of a portion of an absorbent article incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 19 is a cross-sectional view of a portion of another absorbent article incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 20 is a cross-sectional view of a portion of another absorbent article incorporating a reticulated absorbent composite formed in accordance with the present invention;

FIGURES 21A and B are cross-sectional views of portions of reticulated absorbent composites formed in accordance with the present invention;

FIGURE 22 is a diagrammatic view illustrating a twin-wire device and method for forming the composite of the present invention;

5       FIGURE 23 is a diagrammatic view illustrating a representative headbox assembly and method for forming the composite of the present invention;

FIGURE 24 are cross-sectional views of portions of absorbent constructs incorporating an acquisition layer and a reticulated absorbent composite formed in accordance with the present invention;

10       FIGURE 25 are cross-sectional views of portions of absorbent constructs incorporating an acquisition layer, intermediate layer, and a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 26 are cross-sectional views of portions of absorbent articles incorporating a reticulated absorbent composite formed in accordance with the present invention;

15       FIGURE 27 are cross-sectional views of portions of absorbent articles incorporating an acquisition layer and a reticulated absorbent composite formed in accordance with the present invention;

FIGURE 28 are cross-sectional views of portions of absorbent articles incorporating an acquisition layer, intermediate layer, and a reticulated absorbent composite formed in accordance with the present invention;

20       FIGURE 29 is a graph illustrating the correlation between composite edgewise compression and percentage matrix fiber in the composite; and

FIGURE 30 is a graph illustrating the correlation between composite dry tensile strength and edgewise compression.

#### Detailed Description of the Preferred Embodiment

The absorbent composite formed in accordance with the present invention is a reticulated fibrous composite that includes absorbent material. The absorbent material is distributed substantially throughout the fibrous composite and serves to absorb and retain liquid acquired by the composite. In a preferred embodiment, the absorbent material is a superabsorbent material. In addition to forming a matrix for the absorbent material, the composite's fibers provide a stable three-dimensional network of channels or capillaries that serve to acquire liquid contacting the composite and to distribute the acquired liquid to the absorbent material. The composite optionally includes a wet strength agent that further increases tensile strength and structural integrity to the composite.

The composite is a fibrous matrix that includes absorbent material. The fibrous matrix defines voids and passages between the voids, which are distributed throughout the composite. Absorbent material is located within some of the voids. The absorbent material located in these voids is expandable into the void.

5       The absorbent composite can be advantageously incorporated into a variety of absorbent articles such as diapers and training pants; feminine care products including sanitary napkins, tampons, and pant liners; adult incontinence products; toweling; surgical and dental sponges; bandages; food tray pads; and the like.

10       Because the composite is highly absorbent having a high liquid storage capacity, the composite can be incorporated into an absorbent article as a liquid storage core. In such a construct, the composite can be combined with one or more other composites or layers including, for example, an acquisition and/or distribution layer. In a preferred embodiment, an absorbent article, such as a diaper, includes an acquisition layer overlying a reticulated storage core and having a liquid pervious  
15       facing sheet and a liquid impervious backing sheet. Because of the composite's capacity to rapidly acquire and distribute liquid, the composite can serve as a liquid management layer that acquires and transfers a portion of the acquired liquid to an underlying storage layer. Thus, in another embodiment, the absorbent composite can be combined with a storage layer to provide an absorbent core that is useful in  
20       absorbent articles.

      The absorbent composite formed in accordance with the present invention is a reticulated absorbent composite. As used herein, the term "reticulated" refers to the composite's open and porous nature characterized as having a stable three-dimensional network of fibers (i.e., fibrous matrix) that create channels or capillaries that serve to  
25       rapidly acquire and distribute liquid throughout the composite, ultimately delivering acquired liquid to the absorbent material that is distributed throughout the composite.

      The reticulated composite is an open and stable structure. The fibrous composite's open and stable structure includes a network of capillaries or channels that are effective in acquiring and distributing liquid throughout the composite. In the  
30       composite, fibers form relatively dense bundles that direct fluid throughout the composite and to absorbent material distributed throughout the composite. The composite's wet strength agent serves to stabilize the fibrous structure by providing interfiber bonding. The interfiber bonding assists in providing a composite having a stable structure in which the composite's capillaries or channels remain open before,  
35       during, and after liquid insult. The composite's stable structure provides capillaries

that remain open after initial liquid insult and that are available for acquiring and distributing liquid on subsequent insults.

Referring to FIGURE 1, a representative reticulated absorbent composite indicated generally by reference numeral 10 formed in accordance with the present invention is a fibrous matrix that includes fibrous regions 12 substantially composed of  
5 fibers 16 and defining voids 14. Some voids include absorbent material 18. Voids 14 are distributed throughout composite 10.

Representative reticulated composites formed in accordance with the invention are shown in FIGURES 2-9. These composites include 48 percent by weight matrix  
10 fibers (i.e., southern pine commercially available from Weyerhaeuser Co. under the designation NB416), 12 percent by weight resilient fibers (i.e., polymaleic acid crosslinked fibers), 40 percent by weight absorbent material (i.e., superabsorbent material commercially available from Stockhausen), and about 0.5 percent by weight  
15 wet strength agent (i.e., polyamide-epichlorohydrin resin commercially available from Hercules under the designation Kymene®). FIGURE 2 is a photomicrograph of a cross section of a representative composite formed by a wetlaid process at 12 × magnification. FIGURE 3 is a photomicrograph of the same cross section at 40 × magnification. FIGURE 4 is a photomicrograph of a cross section of a representative  
20 composite formed by a foam process at 12 × magnification. FIGURE 5 is a photomicrograph of the same cross section at 40 × magnification. The reticulated nature of the composites is shown in these figures. Referring to FIGURE 3, fibrous regions extend throughout the composite creating a network of channels. Void regions, including those that include absorbent material, appear throughout the composite and are in fluid communication with the composite's fibrous regions.  
25 Absorbent material appears in the composite's voids, generally surrounded by dense fiber bundles.

Photomicrographs of the representative composites shown in FIGURES 2-5 in a wetted state are illustrated in FIGURES 6-9, respectively. These photomicrographs were obtained by sectioning freeze-dried composites that had acquired synthetic urine  
30 under free swell conditions. FIGURES 6 and 7 are photomicrographs of the wetted wetlaid composite at 8 × and 12 × magnification, respectively. FIGURES 8 and 9 are photomicrographs of the wetted foam-formed composite at 8 × and 12 × magnification, respectively. Referring to FIGURE 6, absorbent material in the wetted composite has swollen and increased in size to more fully occupy voids that the  
35 absorbent material previously occupied in the dry composite.



The composite's fibrous matrix is composed primarily of fibers. Generally, fibers are present in the composite in an amount from about 20 to about 90 weight percent, preferably from about 50 to about 70 weight percent, based on the total weight of the composite. Fibers suitable for use in the present invention are known to those skilled in the art and include any fiber from which a wet composite can be formed.

The composite includes resilient fibers. As used herein, the term "resilient fiber" refers to a fiber present in the composite that imparts reticulation to the composite. Generally, resilient fibers provide the composite with bulk and resiliency. The incorporation of resilient fibers into the composite allows the composite to expand on absorption of liquid without structural integrity loss. Resilient fibers also impart softness to the composite. In addition, resilient fibers offer advantages in the composite's formation processes. Because of the porous and open structure resulting from wet composites that include resilient fibers, these composites drain water relatively easily and are therefore dewatered and dried more readily than wet composites that do not include resilient fibers. In one embodiment, the composite includes resilient fibers in an amount from about 5 to about 60 percent by weight, preferably from about 10 to 40 percent by weight, based on the total weight of the composite.

Resilient fibers include cellulosic and synthetic fibers. Resilient fibers include chemically stiffened fibers, anfractuous fibers, chemithermomechanical pulp (CTMP), and prehydrolyzed kraft pulp (PHKP).

The term "chemically stiffened fiber" refers to a fiber that has been stiffened by chemical means to increase fiber stiffness under dry and wet conditions. Fibers can be stiffened by the addition of chemical stiffening agents that can coat and/or impregnate the fibers. Stiffening agents include the polymeric wet strength agents including resinous agents such as, for example, polyamide-epichlorohydrin and polyacrylamide resins described below. Fibers can also be stiffened by modifying fiber structure by, for example, chemical crosslinking. In one embodiment, the chemically stiffened fibers are intrafiber crosslinked cellulosic fibers.

Resilient fibers can include noncellulosic fibers including, for example, synthetic fibers such as polyolefin, polyamide, and polyester fibers. In one embodiment, the resilient fibers include crosslinked cellulosic fibers.

As used herein, the term "anfractuous fiber" refers to a cellulosic fiber that has been chemically treated. Anfractuous fibers include, for example, fibers that have been treated with ammonia.

In addition to resilient fibers, the composite includes matrix fibers. As used herein, the term "matrix fiber" refers to a fiber that is capable of forming hydrogen bonds with other fibers. Matrix fibers are included in the composite to impart strength to the composite. Matrix fibers include cellulosic fibers such as wood pulp fibers, highly refined cellulosic fibers, and high surface area fibers such as expanded cellulose fibers. Other suitable cellulosic fibers include cotton linters, cotton fibers, and hemp fibers, among others. Mixtures of fibers can also be used. In one embodiment, the composite includes matrix fibers in an amount from about 10 to about 60 percent by weight, preferably from about 20 to about 50 percent by weight, based on the total weight of the composite.

The composite can include a combination of resilient and matrix fibers. In one embodiment, the composite includes resilient fibers in an amount from about 5 to about 20 percent by weight and matrix fibers in an amount from about 20 to about 60 percent by weight based on the total weight of the composite. In another embodiment, the composite includes from about 10 to about 15 percent by weight resilient fibers, preferably crosslinked cellulosic fibers, and from about 40 to about 50 percent by weight matrix fibers, preferably wood pulp fibers, based on the total weight of the composite.

Cellulosic fibers are a basic component of the absorbent composite. Although available from other sources, cellulosic fibers are derived primarily from wood pulp. Suitable wood pulp fibers for use with the invention can be obtained from well-known chemical processes such as the kraft and sulfite processes, with or without subsequent bleaching. The pulp fibers may also be processed by thermomechanical, chemithermomechanical methods, or combinations thereof. The preferred pulp fiber is produced by chemical methods. Ground wood fibers, recycled or secondary wood pulp fibers, and bleached and unbleached wood pulp fibers can be used. Softwoods and hardwoods can be used. Details of the selection of wood pulp fibers are well known to those skilled in the art. These fibers are commercially available from a number of companies, including Weyerhaeuser Company, the assignee of the present invention. For example, suitable cellulose fibers produced from southern pine that are usable with the present invention are available from Weyerhaeuser Company under the designations CF416, NF405, PL416, FR516, and NB416.

The wood pulp fibers can also be pretreated prior to use with the present invention. This pretreatment may include physical treatment, such as subjecting the fibers to steam, or chemical treatment, for example, crosslinking the cellulose fibers using any one of a variety of crosslinking agents. Crosslinking increases fiber bulk

and resiliency, and thereby can improve the fibers' absorbency. Generally, crosslinked fibers are twisted or crimped. The use of crosslinked fibers allows the composite to be more resilient, softer, bulkier, have better wicking, and be easier to densify than a composite that does not include crosslinked fibers. Suitable crosslinked cellulose  
5 fibers produced from southern pine are available from Weyerhaeuser Company under the designation NHB416. Crosslinked cellulose fibers and methods for their preparation are disclosed in U.S. Patents Nos. 5,437,418 and 5,225,047 issued to Graef et al., expressly incorporated herein by reference.

Intrafiber crosslinked cellulosic fibers are prepared by treating cellulose fibers  
10 with a crosslinking agent. Suitable cellulose crosslinking agents include aldehyde and urea-based formaldehyde addition products. See, for example, U.S. Patents Nos. 3,224,926; 3,241,533; 3,932,209; 4,035,147; 3,756,913; 4,689,118; 4,822,453; U.S. Patent No. 3,440,135, issued to Chung; U.S. Patent No. 4,935,022, issued to Lash et al.; U.S. Patent No. 4,889,595, issued to Herron et al.; U.S. Patent  
15 No. 3,819,470, issued to Shaw et al.; U.S. Patent No. 3,658,613, issued to Steijer et al.; and U.S. Patent No. 4,853,086, issued to Graef et al., all of which are expressly incorporated herein by reference in their entirety. Cellulose fibers have also been crosslinked by carboxylic acid crosslinking agents including polycarboxylic acids. U.S. Patents Nos. 5,137,537; 5,183,707; and 5,190,563, describe the use of C<sub>2</sub>-C<sub>9</sub>  
20 polycarboxylic acids that contain at least three carboxyl groups (e.g., citric acid and oxydisuccinic acid) as crosslinking agents.

Suitable urea-based crosslinking agents include methylolated ureas, methylolated cyclic ureas, methylolated lower alkyl cyclic ureas, methylolated dihydroxy cyclic ureas, dihydroxy cyclic ureas, and lower alkyl substituted cyclic  
25 ureas. Specific preferred urea-based crosslinking agents include dimethyldihydroxyethylene urea (DMeDHEU, 1,3-dimethyl-4,5-dihydroxy-2-imidazolidinone), dimethyloldihydroxyethylene urea (DMDHEU, 1,3-dihydroxymethyl-4,5-dihydroxy-2-imidazolidinone), dimethylol urea (DMU, bis[N-hydroxymethyl]urea), dihydroxyethylene urea (DHEU, 4,5-dihydroxy-2-imidazolidinone), and dimethyloethylene urea (DMEU, 1,3-dihydroxymethyl-2-imidazolidinone).  
30

Suitable polycarboxylic acid crosslinking agents include citric acid, tartaric acid, malic acid, succinic acid, glutaric acid, citraconic acid, itaconic acid, tartrate monosuccinic acid, and maleic acid. Other polycarboxylic acid crosslinking agents  
35 include polymeric polycarboxylic acids such as poly(acrylic acid), poly(methacrylic acid), poly(maleic acid), poly(methylvinylether-co-maleate) copolymer,

poly(methylvinylether-co-itaconate) copolymer, copolymers of acrylic acid, and copolymers of maleic acid. The use of polymeric polycarboxylic acid crosslinking agents such as polyacrylic acid polymers, polymaleic acid polymers, copolymers of acrylic acid, and copolymers of maleic acid is described in U.S. patent application  
5 Serial No. 08/989,697, filed December 12, 1997, and assigned to Weyerhaeuser Company. Mixtures or blends of crosslinking agents can also be used.

The crosslinking agent can include a catalyst to accelerate the bonding reaction between the crosslinking agent and cellulose fiber. Suitable catalysts include  
10 acidic salts, such as ammonium chloride, ammonium sulfate, aluminum chloride, magnesium chloride, and alkali metal salts of phosphorous-containing acids.

Although not to be construed as a limitation, examples of pretreating fibers include the application of surfactants or other liquids that modify the surface chemistry of the fibers. Other pretreatments include incorporation of antimicrobials, pigments, dyes and densification or softening agents. Fibers pretreated with other  
15 chemicals, such as thermoplastic and thermosetting resins, also may be used. Combinations of pretreatments also may be employed. Similar treatments can also be applied after the composite formation in post-treatment processes.

Cellulosic fibers treated with particle binders and/or densification/softness aids known in the art can also be employed in accordance with the present invention. The  
20 particle binders serve to attach other materials, such as cellulosic fiber superabsorbent polymers, as well as others, to the cellulosic fibers. Cellulosic fibers treated with suitable particle binders and/or densification/softness aids and the process for combining them with cellulose fibers are disclosed in the following U.S. patents: (1) Patent No. 5,543,215, entitled "Polymeric Binders for Binding Particles to Fibers"; (2)  
25 Patent No. 5,538,783, entitled "Non-Polymeric Organic Binders for Binding Particles to Fibers"; (3) Patent No. 5,300,192, entitled "Wet Laid Fiber Sheet Manufacturing With Reactivable Binders for Binding Particles to Binders"; (4) Patent No. 5,352,480, entitled "Method for Binding Particles to Fibers Using Reactivable Binders"; (5) Patent No. 5,308,896, entitled "Particle Binders for High-Bulk Fibers";  
30 (6) Patent No. 5,589,256, entitled "Particle Binders that Enhance Fiber Densification"; (7) Patent No. 5,672,418, entitled "Particle Binders"; (8) Patent No. 5,607,759, entitled "Particle Binding to Fibers"; (9) Patent No. 5,693,411, entitled "Binders for Binding Water Soluble Particles to Fibers"; (10) Patent No. 5,547,745, entitled "Particle Binders"; (11) Patent No. 5,641,561, entitled "Particle Binding to  
35 Fibers"; (12) Patent No. 5,308,896, entitled "Particle Binders for High-Bulk Fibers"; (13) Patent No. 5,498,478, entitled "Polyethylene Glycol as a Binder Material for

Fibers"; (14) Patent No. 5,609,727, entitled "Fibrous Product for Binding Particles"; (15) Patent No. 5,571,618, entitled "Reactivatable Binders for Binding Particles to Fibers"; (16) Patent No. 5,447,977, entitled "Particle Binders for High Bulk Fibers"; (17) Patent No. 5,614,570, entitled "Absorbent Articles Containing Binder Carrying High Bulk Fibers; (18) Patent No. 5,789,326, entitled "Binder Treated Fibers"; and (19) Patent No. 5,611,885, entitled "Particle Binders", all expressly incorporated herein by reference.

In addition to natural fibers, synthetic fibers including polymeric fibers, such as polyolefin, polyamide, polyester, polyvinyl alcohol, and polyvinyl acetate fibers may also be used in the absorbent composite. Suitable polyolefin fibers include polyethylene and polypropylene fibers. Suitable polyester fibers include polyethylene terephthalate fibers. Other suitable synthetic fibers include, for example, nylon fibers. The absorbent composite can include combinations of natural and synthetic fibers.

In one embodiment, the absorbent composite includes a combination of wood pulp fibers (e.g., Weyerhaeuser designation NB416) and crosslinked cellulosic fibers (e.g., Weyerhaeuser designation NHB416). Wood pulp fibers are present in such a combination in an amount from about 10 to about 85 weight percent by weight based on the total weight of fibers.

When incorporated into an absorbent article, the reticulated absorbent composite can serve as a storage layer for acquired liquids. To effectively retain acquired liquids, the absorbent composite includes absorbent material. As used herein, the term "absorbent material" refers to a material that absorbs liquid and that generally has an absorbent capacity greater than the cellulosic fibrous component of the composite. Preferably, the absorbent material is a water-swellaable, generally water-insoluble polymeric material capable of absorbing at least about 5, desirably about 20, and preferably about 100 times or more its weight in saline (e.g., 0.9 percent saline). The absorbent material can be swellaable in the dispersion medium utilized in the method for forming the composite. In one embodiment, the absorbent material is untreated and swellaable in the dispersion medium. In another embodiment, the absorbent material is a coated absorbent material that is resistant to absorbing water during the composite formation process.

The amount of absorbent material present in the composite can vary greatly depending on the composite's intended use. The amount of absorbent material present in an absorbent article, such as an absorbent core for an infant's diaper, is suitably present in the composite in an amount from about 5 to about 60 weight

percent, preferably from about 30 to about 50 weight percent, based on the total weight of the composite.

The absorbent material may include natural materials such as agar, pectin, and guar gum, and synthetic materials, such as synthetic hydrogel polymers. Synthetic hydrogel polymers include, for example, carboxymethyl cellulose, alkaline metal salts of polyacrylic acid, polyacrylamides, polyvinyl alcohol, ethylene maleic anhydride copolymers, polyvinyl ethers, hydroxypropyl cellulose, polyvinyl morpholinone, polymers and copolymers of vinyl sulphonic acid, polyacrylates, polyacrylamides, and polyvinyl pyridine among others. In one embodiment, the absorbent material is a superabsorbent material. As used herein, a "superabsorbent material" refers to a polymeric material that is capable of absorbing large quantities of fluid by swelling and forming a hydrated gel (i.e., a hydrogel). In addition to absorbing large quantities of fluids, superabsorbent materials can also retain significant amounts of bodily fluids under moderate pressure.

Superabsorbent materials generally fall into three classes: starch graft copolymers, crosslinked carboxymethylcellulose derivatives, and modified hydrophilic polyacrylates. Examples of such absorbent polymers include hydrolyzed starch-acrylonitrile graft copolymers, neutralized starch-acrylic acid graft copolymers, saponified acrylic acid ester-vinyl acetate copolymers, hydrolyzed acrylonitrile copolymers or acrylamide copolymers, modified crosslinked polyvinyl alcohol, neutralized self-crosslinking polyacrylic acids, crosslinked polyacrylate salts, carboxylated cellulose, and neutralized crosslinked isobutylene-maleic anhydride copolymers.

Superabsorbent materials are available commercially, for example, polyacrylates from Clariant of Portsmouth, Virginia. These superabsorbent polymers come in a variety of sizes, morphologies, and absorbent properties (available from Clariant under trade designations such as IM 3500 and IM 3900). Other superabsorbent materials are marketed under the trademarks SANWET (supplied by Sanyo Kasei Kogyo Kabushiki Kaisha), and SXM77 (supplied by Stockhausen of Greensboro, North Carolina). Other superabsorbent materials are described in U.S. Patent No. 4,160,059; U.S. Patent No. 4,676,784; U.S. Patent No. 4,673,402; U.S. Patent No. 5,002,814; U.S. Patent No. 5,057,166; U.S. Patent No. 4,102,340; and U.S. Patent No. 4,818,598, all expressly incorporated herein by reference. Products such as diapers that incorporate superabsorbent materials are described in U.S. Patent No. 3,699,103 and U.S. Patent No. 3,670,731.

Suitable superabsorbent materials useful in the absorbent composite include superabsorbent particles and superabsorbent fibers.

In one embodiment, the absorbent composite includes a superabsorbent material that swells relatively slowly for the purposes of composite manufacturing and yet swells at an acceptable rate so as not to adversely affect the absorbent characteristics of the composite or any construct containing the composite. Generally, the smaller the absorbent material, the more rapidly the material absorbs liquid.

The absorbent composite can optionally include a wet strength agent. The wet strength agent provides increased strength to the absorbent composite and enhances the composite's wet integrity. In addition to increasing the composite's wet strength, the wet strength agent can assist in binding the absorbent material, for example, superabsorbent material, in the composite's fibrous matrix.

Suitable wet strength agents include cationic modified starch having nitrogen-containing groups (e.g., amino groups) such as those available from National Starch and Chemical Corp., Bridgewater, NJ; latex; wet strength resins such as polyamide-epichlorohydrin resin (e.g., Kymene® 557LX, Hercules, Inc., Wilmington, DE), polyacrylamide resin (described, for example, in U.S. Patent No. 3,556,932 issued January 19, 1971 to Coscia et al.; also, for example, the commercially available polyacrylamide marketed by American Cyanamid Co., Stamford, CT, under the trade name Parex™ 631 NC); urea formaldehyde and melamine formaldehyde resins, and polyethylenimine resins. A general discussion on wet strength resins utilized in the paper field, and generally applicable in the present invention, can be found in TAPPI monograph series No. 29, "Wet Strength in Paper and Paperboard", Technical Association of the Pulp and Paper Industry (New York, 1965).

Generally, the wet strength agent is present in the composition in an amount from about 0.01 to about 2 weight percent, preferably from about 0.1 to about 1 weight percent, and more preferably from about 0.3 to about 0.7 weight percent, based on the total weight of the composite. In a preferred embodiment, the wet strength agent useful in forming the composite is a polyamide-epichlorohydrin resin commercially available from Hercules, Inc. under the designation Kymene®. The wet and dry tensile strengths of an absorbent composite formed in accordance with the present invention will generally increase with an increasing the amount of wet strength agent. The tensile strength of a representative composite is described in Example 7.

The absorbent composite generally has a basis weight from about 50 to about 1000 g/m<sup>2</sup>, preferably from about 200 to about 800 g/m<sup>2</sup>. In one embodiment, the absorbent composite has a basis weight from about 300 to about 600 g/m<sup>2</sup>. The

absorbent composite generally has a density from about 0.02 to about 0.7 g/cm<sup>3</sup>, preferably from about 0.04 to about 0.3 g/cm<sup>3</sup>. In one embodiment, the absorbent composite has a density of about 0.15 g/cm<sup>3</sup>.

In one embodiment, the absorbent composite is a densified composite.

5     Densification methods useful in producing the densified composites are well known to those in the art. See, for example, U.S. Patent No. 5,547,541 and patent application Serial No. 08/859,743, filed May 21, 1997, entitled "Softened Fibers and Methods of Softening Fibers," assigned to Weyerhaeuser Company, both expressly incorporated herein by reference. Post-dryer densified absorbent reticulated storage composites  
10    generally have a density from about 0.1 to about 0.5 g/cm<sup>3</sup>, and preferably about 0.15 g/cm<sup>3</sup>. Predryer densification can also be employed. In one embodiment, the absorbent composite is densified by either a heated or room temperature calender roll method. See, for example, U.S. Patents Nos. 5,252,275 and 5,324,575, both expressly incorporated herein by reference.

15    The composition of the reticulated absorbent composite can be varied to suit the needs of the desired end product in which it can be incorporated. In one embodiment, the absorbent composite includes about 60 weight percent cellulosic fibers (about 48 percent by weight wood pulp fibers and about 12 percent by weight crosslinked cellulosic fibers), about 40 percent by weight absorbent material (e.g.,  
20    superabsorbent particles), and about 0.5 percent by weight wet strength agent (e.g., polyamide-epichlorohydrin resin, Kymene®, about 10 pounds resin per ton fiber) based on the total weight of the composite.

The reticulated absorbent composite can be formed by wetlaid and foam processes known to those of ordinary skill in the pulp processing art. A  
25    representative example of a wetlaid process is described in U.S. Patent No. 5,300,192, issued April 5, 1994, entitled "Wetlaid Fiber Sheet Manufacturing with Reactivable Binders for Binding Particles to Fibers", expressly incorporated herein by reference. Wetlaid processes are also described in standard texts, such as Casey, PULP AND PAPER, 2nd edition, 1960, Volume II, Chapter VIII - Sheet Formation.  
30    Representative foam processes useful in forming the composite are known in the art and include those described in U.S. Patents Nos. 3,716,449; 3,839,142; 3,871,952; 3,937,273; 3,938,782; 3,947,315; 4,166,090; 4,257,754; and 5,215,627, assigned to Wiggins Teape and related to the formation of fibrous materials from foamed aqueous fiber suspensions, and "The Use of an Aqueous Foam as a Fiber-Suspending Medium  
35    in Quality Papermaking," Foams, Proceedings of a Symposium organized by the Society of Chemical Industry, Colloid and Surface Chemistry Group, R.J. Akers, Ed.,



Academic Press, 1976, which describes the Radfoam process, all expressly incorporated herein by reference.

In the methods, the absorbent material is incorporated into the composite during the formation of the composite. Generally, the methods for forming the  
5 reticulated absorbent composite include combining the components of the composite in a dispersion medium (e.g., an aqueous medium) to form a slurry and then depositing the slurry onto a foraminous support (e.g., a forming wire) and dewatering to form a wet composite. Drying the wet composite provides the reticulated composite.

10 As noted above, the reticulated composite is prepared from a combination of fibers, absorbent material, and optionally a wet strength agent in a dispersion medium. In one embodiment of the method, a slurry is formed by directly combining fibers, absorbent material, and wet strength agent in a dispersion medium. In another  
15 embodiment, the slurry is prepared by first combining fibers and the wet strength agent in a dispersion medium to provide a fibrous slurry to which is then added absorbent material in a second step. In yet another embodiment, a fibrous slurry is combined with a second slurry containing absorbent material, the combined slurry then being deposited onto the support. Alternatively, individual slurries, for example,  
20 a fibrous slurry and a slurry containing absorbent material, can be deposited onto the foraminous support through the use of a divided headbox, for example, a twin slice headbox that deposits two slurries onto a support simultaneously.

In one embodiment, the slurry or slurries containing the composite's components in a dispersion medium are deposited onto a foraminous support. Once deposited onto the support the dispersion medium begins to drain from the deposited  
25 fibrous slurry. Removal of the dispersion medium (e.g., dewatering) from the deposited fibrous slurry continues through, for example, the application of heat, pressure, vacuum, and combinations thereof, and results in the formation of a wet composite.

The reticulated absorbent composite can be ultimately produced by drying the  
30 wet composite. Drying removes the remaining dispersion medium and provides an absorbent composite having the desired moisture content. Generally, the composite has a moisture content less than about 20 percent and, in one embodiment, has a moisture content in the range from about 6 to about 10 percent by weight based on the total weight of the composite. Suitable composite drying methods include, for  
35 example, the use of drying cans, air floats, and through air dryers. Other drying methods and apparatus known in the pulp and paper industry may also be used.

Drying temperatures, pressures, and times are typical for the equipment and methods used, and are known to those of ordinary skill in the art in the pulp and paper industry. A representative wetlaid method for forming a reticulated absorbent composite is described in Example 1.

5 For foam methods, the fibrous slurry is a foam dispersion that further includes a surfactant. Suitable surfactants include ionic, nonionic, and amphoteric surfactants known in the art. A representative foam method for forming a reticulated absorbent composite is described in Example 2.

10 The deposition of the components of the absorbent composite onto the foraminous support, followed by dewatering, results in the formation of a wet composite that includes absorbent material that may have absorbed water and, as a result, swollen in size. The wet composite containing the water-swollen absorbent material is distributed onto a support from which water (i.e., the dispersion medium) can be withdrawn and the wet composite dried. Drying causes the water-swollen  
15 absorbent material to dehydrate and decrease in size, thereby creating voids in the composite surrounding the absorbent material.

In the methods, the absorbent material preferably absorbs less than about 20 times its weight in the dispersion medium, more preferably less than about 10 times, and even more preferably less than about 5 times its weight in the dispersion medium.

20 Foam methods are advantageous for forming the absorbent composite for several reasons. Generally, foam methods provide fibrous webs that possess both relatively low density and relatively high tensile strength. For webs composed of substantially the same components, foam-formed webs generally have densities greater than air-laid webs and lower than wetlaid webs. Similarly, the tensile strength of  
25 foam-formed webs is substantially greater than for air-laid webs and approach the strength of wetlaid webs. Also, the use of foam forming technology allows better control of pore and void size, void size to be maximized, the orientation and uniform distribution of fibers, and the incorporation of a wide range of materials (e.g., long and synthetic fibers that cannot be readily incorporated into wetlaid processes) into  
30 the composite.

For fabrication, the reticulated absorbent composite can be formed by a foam process, preferably a process by Ahlstrom Company (Helsinki, Finland). The process encompasses desirable manufacturing efficiencies while producing a product with desirable performance characteristics.

35 The formation of a reticulated absorbent composite by representative wetlaid and foam processes is described in Examples 1 and 2, respectively. Absorbent

properties (i.e., rewet, acquisition time, liquid distribution, dry strength, and resilience) for representative reticulated absorbent composites are described in Examples 3 and 4. Wicking and liquid distribution for a representative absorbent composite are described in Examples 5 and 6, respectively. The tensile strength of representative composites formed in accordance with the present invention is described in Example 7. The softness (i.e., Taber stiffness) of representative wetlaid and foam-formed composites is described in Example 8.

One variable that affects the absorbent composite's performance characteristics including, for example, liquid acquisition and distribution rate and absorbent capacity, is the extent of swelling of the absorbent material in the composite. The methods allow for control and variation of absorbent material swelling. Absorbent material swelling generally depends on the degree of its crosslinking (e.g., surface and internal crosslinking) and the amount of water absorbed by the absorbent material. The extent of swelling depends on a number of factors, including the type of absorbent material, the concentration of absorbent material in an aqueous environment (e.g., the dispersion medium and the wet composite), and the period of time that the absorbent material remains in contact with such an environment. Generally, the lower the concentration of the absorbent material in an aqueous medium and the longer the contact time, the greater the swelling of an absorbent material. Absorbent material swelling can be minimized by dispensing the absorbent in chilled water.

In general, the greater the initial swelling of the absorbent material, the greater the void volume and, consequently, the lower the density of the resulting absorbent composite. The greater the void volume of a composite, the greater its liquid acquisition rate and, generally, the greater the composite's absorbent capacity.

As noted above, the composite's voids are formed by the hydration and swelling of absorbent material (i.e., during wet composite formation) and the subsequent dehydration and decrease in size of the absorbent material (i.e., during wet composite drying). Ultimately, the density of the composite depends on the extent to which the absorbent material absorbs liquid and swells during the formation of the wet composite, and the conditions and extent to which the wet composite incorporating the swollen absorbent material is dried. Water absorbed by the absorbent material during wet composite formation is removed from the absorbent material, decreasing its size, on drying the wet composite. The dehydration of the swollen absorbent material defines some of the voids in the fibrous composite.

The reticulated absorbent composite can be incorporated as an absorbent core or storage layer in an absorbent article including, for example, a diaper or feminine care product. The absorbent composite can be used alone or, as illustrated in FIGURES 10 and 11, can be used in combination with one or more other layers. In  
5 FIGURE 10, absorbent composite 10 is employed as a storage layer in combination with upper acquisition layer 20. As illustrated in FIGURE 11, a third layer 30 (e.g., distribution layer) can also be employed, if desired, with absorbent composite 10 and acquisition layer 20.

A variety of suitable absorbent articles can be produced from the absorbent  
10 composite. The most common include absorptive consumer products, such as diapers, feminine hygiene products such as feminine napkins, and adult incontinence products. For example, referring to FIGURE 12A, absorbent article 38 comprises composite 10, liquid pervious facing sheet 22 and liquid impervious backing sheet 24. Referring to FIGURE 12B, absorbent article 40 comprises absorbent composite 10  
15 and overlying acquisition layer 20. A liquid pervious facing sheet 22 overlies acquisition composite 20, and a liquid impervious backing sheet 24 underlies absorbent composite 10. The absorbent composite will provide advantageous liquid absorption performance for use in, for example, diapers. The reticulated structure of the absorbent composite will aid in fluid transport and absorption in multiple wettings.  
20 For absorbent articles that incorporate the composite and that are suitable for use as diapers or as incontinence products, the articles can further include leg gathers.

The constructs in FIGURES 12A and 12B are shown for purposes of exemplifying a typical absorbent article, such as a diaper or feminine napkin. One of ordinary skill will be able to make a variety of different constructs using the concepts  
25 taught herein. The example, a typical construction of an adult incontinence absorbent structure is shown in FIGURE 13. The article 50 comprises a facing sheet 22, acquisition layer 20, absorbent composite 10, and a backing sheet 24. The facing sheet 22 is pervious to liquid while the backing sheet 24 is impervious to liquid. In this construct, a liquid pervious tissue 26 composed of a polar, fibrous material is  
30 positioned between absorbent composite 10 and acquisition layer 20.

Referring to FIGURE 14, another absorbent article includes a facing sheet 22, an acquisition layer 20, an intermediate layer 28, absorbent composite 10, and a backing sheet 24. The intermediate layer 28 contains, for example, a densified fibrous material such as a combination of cellulose acetate and triacetin, which are combined  
35 prior to forming the article. The intermediate layer 28 can thus bond to both absorbent composite 10 and acquisition layer 20 to form an absorbent article having

significantly more integrity than one in which the absorbent composite and acquisition layer are not bonded to each other. The hydrophilicity of layer 28 can be adjusted in such a way as to create a hydrophilicity gradient among layers 10, 28, and 20.

5 The reticulated absorbent composite can also be incorporated as a liquid management layer in an absorbent article such as a diaper. In such an article, the composite can be used in combination with a storage core or layer. In the combination, the liquid management layer can have a top surface area that is smaller, the same size, or greater than the top surface area of the storage layer. Representative absorbent constructs that incorporate the reticulated absorbent composite in  
10 combination with a storage layer are shown in FIGURE 15. Referring to FIGURE 15, absorbent construct 70 includes reticulated composite 10 and storage layer 72. Storage layer 72 is preferably a fibrous layer that includes absorbent material. The storage layer can be formed by any method, including airlaid, wetlaid, and foam-forming methods. The storage layer can be a reticulated composite.

15 An acquisition layer can be combined with the reticulated composite and storage layer. FIGURE 16 illustrates absorbent construct 80 having acquisition layer 20 overlying composite 10 and storage layer 72. Construct 80 can further include intermediate layer 74 to provide construct 90 shown in FIGURE 17. Intermediate layer 74 can be, for example, a tissue layer, a nonwoven layer, an airlaid or wetlaid pad, or a reticulated composite.  
20

Constructs 70, 80, and 90 can be incorporated into absorbent articles. Generally, absorbent articles 100, 110, and 120, shown in FIGURES 18-20, respectively, include a liquid pervious facing sheet 22, a liquid impervious backing sheet 24, and constructs 70, 80, and 90, respectively. In such absorbent articles, the  
25 facing sheet is joined to the backing sheet.

In another embodiment, the reticulated absorbent composite formed in accordance with the present invention further includes a fibrous stratum. In this embodiment, the composite includes a reticulated core and a fibrous stratum adjacent an outward facing surface of the core. The fibrous stratum is integrally formed with  
30 the reticulated core to provide a unitary absorbent composite. As used herein, the term "integrally formed" refers to a composite having more than one strata produced in a formation process that provides the composite as a unitary structure. Generally, the stratum is coextensive with an outward facing surface (i.e., an upper and/or lower surface) of the composite. Preferably, the composite includes first and second strata  
35 adjacent each of the core's outward facing surfaces (i.e., the strata are coextensive with opposing surfaces of the core). A representative absorbent composite having a

fibrous stratum is shown in FIGURE 21A and a representative composite having fibrous strata is shown in FIGURE 21B. Referring to FIGURE 21A, absorbent composite 130 includes reticulated core 10 and stratum 132 and, as shown in FIGURE 21B, composite 140 includes reticulated core 10 intermediate strata 132 and 134. As noted above, core 10 is a fibrous matrix that includes fibrous regions 12 defining voids 14, some of which include absorbent material 18.

In this embodiment, the present invention provides an absorbent composite that is a unitary structure that includes two or more strata. The term "unitary" refers to the composite's structure in which adjacent strata are integrally connected through a transition zone to provide a structure with adjacent strata in intimate fluid communication. Referring to FIGURE 21A, surface stratum 132 is integrally connected to core stratum 10 through a transition zone. Similarly, referring to FIGURE 21B, strata 132 and 134 are each integrally connected to core stratum 10 through a transition zone.

In the composite, transition zones separate the composite's strata. The nature of the transition zone can vary from composite-to-composite and from stratum-to-stratum within a composite. The transition zone can be designed to satisfy the performance requirements of a particular composite. In general, the transition zone integrally connects adjacent strata and provides for intimate liquid communication between strata. The transition zone includes fibers from one stratum extending into the adjacent stratum. For adjacent strata, the transition zone includes fibers from the first stratum extending into the second stratum and fibers from the second stratum extending into the first stratum.

Transition zone thickness within a composite can be widely varied depending on the composite. Absorbent composites of the present invention can include a transition zone that is relatively thin. Absorbent composites that include such thin transition zones have fairly abrupt transitions in material composition between strata. Alternatively, the composite can include a transition zone that is gradual such that the transition from one zone to the next occurs over a relatively greater thickness of the composite. In such a composite, the material compositions of each zone are intermixed to a significant extent resulting in rather extended composition gradients.

Unitary composites having multiple strata and methods for their formation are described in international patent application Serial No. PCT/US97/22342, Unitary Stratified Composite, and U.S. patent application Serial No. 09/326,213, Unitary Absorbent System, each incorporated herein by reference in its entirety.

The stratum or strata of the composite are fibrous and can be composed of any suitable fiber or combination of fibers noted above. The stratum's fibrous composition can be widely varied. The stratum can be formed from fibers that are the same as or different from the fibers used for forming the reticulated core. The stratum  
5 can be formed from resilient fibers, matrix fibers, or combinations of resilient and matrix fibers. The stratum can optionally include a wet or dry strength agent. Suitable strata can be formed from a single fiber type, for example, a stratum composed of 100 percent wood pulp fibers (e.g., southern pine fibers). Alternatively,  
10 the stratum can be formed from fibrous blends, such as an 80:20 blend of wood pulp fibers and crosslinked fibers, and synthetic blends, and blends of synthetic and cellulosic fibers.

The stratum composition can be varied to provide a composite having desired characteristics. For example, to provide a stratum having high liquid wicking capacity, the stratum preferably has a relatively high wood pulp fiber content. Thus,  
15 for liquid distribution, the stratum is preferably composed of wood pulp fibers such as southern pine fibers. However, such a stratum has a lower liquid acquisition rate compared to a similarly constituted stratum containing relatively less wood pulp fiber and, for example, greater amounts of crosslinked fibers. Conversely, to provide a stratum having a high liquid acquisition rate, the stratum preferably has a relatively  
20 high crosslinked or synthetic fiber content. However, as a consequence of its high crosslinked fiber content, such a stratum provides less liquid distribution than a comparable stratum that includes relatively less crosslinked fiber. For liquid acquisition, the stratum is preferably a blend of crosslinked fibers and pulp fibers, for example, the stratum can include from about 30 to about 50 percent by weight  
25 crosslinked fibers and from about 50 to about 70 percent by weight pulp fibers. Alternatively, strata having high liquid acquisition rates can also include, in combination with cellulosic fibers, a relatively high synthetic fiber content (e.g., PET fibers or a blend of PET and thermobondable fibers). Optionally, one or both strata can include synthetic fibers.

30 Because the composite's stratum is formed with the reticulated core to provide an integrated unitary structure, the overall characteristics of the composite can be optimized by appropriate selection of the individual core and stratum components. To further optimize the performance of the composite, the nature of first and second strata can be selectively and independently controlled and varied. The  
35 compositions of the first and second strata need not be the same. The strata can be formed from the same or different fiber furnishes. For compositions formed by foam

methods, stratum basis weight can also be independently controlled and varied. Stratum basis weight can also be varied with respect to the core's basis weight. In a foam method, basis weight can be varied by adjusting the rate at which the fibrous furnish is supplied to and deposited on the forming support. For example, varying  
5 pump speed for a specific furnish effectively controls the basis weight of that portion of the composite. Accordingly, in one embodiment, the absorbent composite includes a reticulated core intermediate first and second strata, each stratum having a different basis weight. Stratum basis weights can also be varied for absorbent composites formed by wetlaid methods.

10 The stratum can be integrally formed with the reticulated core by wetlaid and foam methods. Generally, the composite including the reticulated core and strata can be formed by substantially simultaneously depositing fibrous slurries that include the core and stratum components. The deposition of more than a single fibrous slurry onto a forming support can be accomplished by standard devices known in the art  
15 including, for example, divided and/or multislice headboxes.

Representative absorbent composites can be formed using conventional papermaking machines including, for example, Rotoformer, Fourdrinier, and twin-wire machines. Absorbent composites having a single stratum can be formed by Rotoformer and Fourdrinier machines, and composites that include two strata can be  
20 formed by twin-wire machines. A representative method for forming the absorbent composite using a Rotoformer machine is described in Example 9. The performance characteristics of representative absorbent composites formed by the method are described in Examples 10-15. Absorbent composites formed using the Rotoformer machine include a wire-side fibrous stratum. The stratum thickness and overall  
25 composite structure can be controlled by the position of headbox spargers, which deliver absorbent material to and effectively mix the absorbent material with the fiber stock. Generally, the deeper the sparger introduces the absorbent material into the fiber stock at the Rotoformer drum, the thinner the resulting stratum. Conversely, a relatively thicker stratum can be formed by introducing absorbent material into the  
30 fiber stock at a greater distance from the drum.

The absorbent composite can be formed by devices and processes that include a twin-wire configuration (i.e., twin-forming wires). A representative twin-wire machine for forming composites is shown in FIGURE 22. Referring to FIGURE 22, machine 200 includes twin-forming wires 202 and 204 onto which the composite's  
35 components are deposited. Basically, fibrous slurry 124 is introduced into headbox 212 and deposited onto forming wires 202 and 204 at the headbox exit.



Vacuum elements 206 and 208 dewater the fibrous slurries deposited on wires 202 and 204, respectively, to provide partially dewatered webs that exit the twin-wire portion of the machine as partially dewatered web 126. Web 126 continues to travel along wire 202 and continues to be dewatered by additional vacuum elements 210 to provide wet composite 120 which is then dried by drying means 216 to provide composite 10.

Absorbent material can be introduced into the fibrous web at any one of several positions in the twin-wire process depending on the desired product configuration. Referring to FIGURE 22, absorbent material can be introduced into the partially dewatered web at positions 2, 3, or 4, or other positions along wires 202 and 204 where the web has been at least partially dewatered. Absorbent material can be introduced into the partially dewatered web formed and traveling along wire 202 and/or 204. Absorbent material can be injected into the partially dewatered fibrous webs by nozzles spaced laterally across the width of the wire. The nozzles are connected to an absorbent material supply. The nozzles can be positioned in various positions (e.g., positions 2, 3, or 4 in FIGURE 22) as described above. For example, referring to FIGURE 22, nozzles can be located at positions 2 to inject absorbent material into partially dewatered webs on wires 202 and 204.

Depending on the position of absorbent material introduction, the twin-wire method for forming the composite can provide a composite having fibrous stratum. The composite can include fibrous strata coextensive with the outward surfaces of the composite. These fibrous composites can be formed from multilayered inclined formers or twin-wire formers with sectioned headboxes. These methods can provide stratified composites having strata having specifically designed properties and containing components to attain composites having desired properties.

For example, composite 130 having stratum 132 and composite 140 having strata 132 and 134 can be formed by machine 200. For composites in which strata 132 and 134 comprise the same components, a single fiber furnish 124 is introduced into headbox 212. For forming composites having strata 132 and 134 comprising different components, headbox 212 includes one or more baffles 214 for the introduction of fiber furnishes (e.g., 124a, 124b, and 124c) having different compositions. In such a method, the upper and lower strata can be formed to include different components and have different basis weights and properties.

In one embodiment, the reticulated composite is formed by a foam-forming method using the components described above. In the foam-forming method, fibrous webs having multiple strata and including absorbent material can be formed from

multiple fibrous slurries. The foam-forming method can be practiced on a twin-wire former.

The method can provide a variety of multiple strata composites including, for example, composites having three strata. A representative composite having three  
5 strata includes a first stratum formed from fibers (e.g., synthetic fibers, cellulosic, and/or binder fibers); an intermediate stratum formed from fibers and/or other absorbent material such as superabsorbent material; and a third stratum formed from fibers. The method of the invention is versatile in that such a composite can have relatively distinct and discrete strata or, alternatively, have gradual transition zones  
10 from stratum-to-stratum.

A representative method for forming a fibrous web having an intermediate stratum generally includes the following steps:

- (a) forming a first foam fibrous slurry comprising fibers and a surfactant in an aqueous dispersion medium;
- 15 (b) forming a second foam fibrous slurry comprising fibers and a surfactant in an aqueous dispersion medium;
- (c) moving a first foraminous element (e.g., a forming wire) in a first path;
- (d) moving a second foraminous element in a second path;
- 20 (e) passing the first foam slurry into contact with the first foraminous element moving in a first path;
- (f) passing the second foam slurry into contact with the second foraminous element moving in the second path;
- (g) passing a third material between the first and second foam  
25 slurries such that the third material does not contact either of the first or second foraminous elements; and
- (h) forming a fibrous web from the first and second foam slurries and third material by withdrawing foam and liquid from the slurries through the first and second foraminous elements.

30 As noted above, the method is suitably carried out on a twin-wire former, preferably a vertical former, and more preferably, a vertical downflow twin-wire former. In the vertical former, the paths for the foraminous elements are substantially vertical.

35 A representative vertical downflow twin-wire former useful in practicing the method of the invention is illustrated in FIGURE 23. Referring to FIGURE 23, the former includes a vertical headbox assembly having a former with a closed first end

(top), closed first and second sides and an interior volume. A second end (bottom) of the former is defined by moving first and second foraminous elements, 202 and 204, and forming nip 213. The interior volume defined by the former's closed first end, closed first and second sides, and first and second foraminous elements includes an interior structure 230 extending from the former first end and toward the second end. The interior structure defines a first volume 232 on one side thereof and a second volume 234 on the other side thereof. The former further includes supply 242 and means 243 for introducing a first fiber/foam slurry into the first volume, supply 244 and means 245 for introducing a second fiber/foam slurry into the second volume, and supply 246 and means 247 for introducing a third material into the interior structure. Means for withdrawing foam (e.g., suction boxes 206 and 208) from the first and second slurries through the foraminous elements to form a web are also included in the headbox assembly.

In the method, the twin-wire former includes a means for introducing at least a third material through the interior structure.

Generally, the former's interior structure (i.e., structure 230 in FIGURE 23) is positioned with respect to the foraminous elements such that material introduced through the interior structure will not directly contact the first and second foraminous elements. Accordingly, material is introduced through the interior structure between the first and second slurries after the slurries have contacted the foraminous elements and withdrawal of foam and liquid from those slurries has commenced. Such a configuration is particularly advantageous for introducing superabsorbent materials and for forming stratified structures in which the third material is a superabsorbent material-containing slurry. Depending upon the nature of the composite to be formed, the first and second fiber/foam slurries may be the same, or different, from each other and from the third material.

The means for withdrawing foam from the first and second slurries through the foraminous elements to form a web on the foraminous elements are also included in the headbox assembly. The means for withdrawing foam can include any conventional means for that purpose, such as suction rollers, pressing rollers, or other conventional structures. In a preferred embodiment, first and second suction box assemblies are provided and mounted on the opposite sides of the interior structure from the foraminous elements (see boxes 206 and 208 in FIGURES 22 and 23).

Composite flexibility and softness are factors for determining the suitability of composites for incorporation into personal care absorbent products. Composite flexibility can be indicated by composite edgewise ring crush, which is a measure of

the force required to compress the composite as described below. For a composite to be incorporated into a personal care absorbent product, suitable ring crush values range from about 400 to about 1600 gram/inch. Composite softness can be indicated by a variety of parameters including composite edgewise compression. Edgewise compression (EC) is the force required to compress the composite corrected by the composite's basis weight as described below. For a composite to be suitably incorporated into a personal care absorbent product, the composite has a ring crush value in the range from about 400-1600 g and a basis weight in the range from about 300 to about 600 gsm.

The composites achieve the desired flexibility and softness by adjusting composite composition. Composite flexibility and softness can be adjusted, controlled, and optimized by adjusting the amount and ratio of the composite's components. The composites include three basic components: (1) absorbent material; (2) crosslinked cellulosic fibers; and (3) matrix fibers. Generally, increasing the amount and/or proportion of absorbent material (e.g., superabsorbent material) and/or crosslinked fiber in the composite increases composite flexibility and softness. Conversely, increasing the amount of matrix fiber (e.g., pulp fiber) in the composite generally decreases composite flexibility and softness.

Representative composites of the invention having suitable flexibility and softness include from about 30 to about 80 percent by weight absorbent material, from about 10 to about 50 percent by weight crosslinked fiber, and from about 5 to about 30 percent by weight matrix fiber.

In one embodiment, the composite includes from about 40 to about 70 percent and, preferably, about 60 percent by weight superabsorbent material based on the total weight of the composite; from about 20 to about 50 percent and, preferably, about 30 percent by weight crosslinked fiber; and from about 5 to about 20 percent and, preferably, about 10 percent by weight matrix fiber based on the total weight of the composite. For composites including less than about 50 percent by weight superabsorbent material, the ratio of crosslinked fibers:matrix fibers can be at least 1:1 and, preferably, about 2:1.

In another embodiment, the composite includes about 70 percent by weight superabsorbent material and about 30 percent by weight fibers. In one embodiment, the fibers include a blend of matrix fibers (e.g., southern pine) and crosslinked fibers having a ratio of crosslinked fibers:matrix fibers of at least 1:1 and, preferably, at least about 2:1.

In a further preferred embodiment, the composite includes superabsorbent polymeric particles having an average particle diameter in the range from about 0.50 mm to about 1.0 mm.

5 Examples 17-19 describe the composition and flexibility and softness of representative absorbent composites formed in accordance with the invention. The composites described in Example 17 were formed as handsheets and the composites described in Example 18 were formed by a foam-forming process on a twin-wire former. The effect of superabsorbent polymer particle size on composite flexibility and softness is described in Example 20.

10 In addition to having flexibility and softness suitable for incorporation into personal care absorbent products, the composites of the invention exhibit advantageous structural integrity. Composite structural integrity can be indicated by tensile strength. Suitable composites for use in a personal-care absorbent product have a wet tensile strength of at least about 50 g/in. For machine processing, suitable  
15 composites have a dry tensile strength of at least about 450 g/in.

Generally, as tensile strength increases, composite ring crush increases. The correlation between composite edgewise ring crush and dry tensile is presented graphically in FIGURE 30, which shows that edgewise ring crush increases dramatically as dry tensile increases. Although there appears to be no correlation  
20 between composite basis weight and dry tensile, some correlation exists between composite density and dry tensile.

The tensile strength and edgewise compression of representative composites of the invention are provided in Example 21.

25 The composites of the invention exhibit advantageous fluidic properties. The properties can be indicated by various measures including liquid acquisition rate, wicking, and rewet. Acquisition rate and rewet, unrestrained vertical wicking height, and saddle acquisition rate, distribution, and wicking height for representative composites is described in Example 22.

30 The absorbent composite formed in accordance with the present invention can be incorporated as an absorbent core or storage layer into an absorbent article such as a diaper. The composite can be used alone or combined with one or more other layers, such as acquisition and/or distribution layers, to provide useful absorbent constructs.

35 Representative absorbent constructs incorporating the absorbent composite having a reticulated core and fibrous strata are shown in FIGURES 24 and 25. Referring to FIGURE 24A, construct 150 includes composite 130 (i.e., reticulated

core 10 and stratum 132) employed as a storage layer in combination with an upper acquisition layer 20. FIGURE 24B illustrates construct 160, which includes composite 130 and acquisition layer 20 with stratum 132 adjacent acquisition layer 20. Construct 170, including acquisition layer 20 and composite 140, is illustrated in  
5 FIGURE 24C.

In addition to the constructs noted above that include the combination of absorbent composite and acquisition layer, further constructs can include a distribution layer intermediate the acquisition layer and composite. FIGURE 25A  
10 illustrates construct 180 having intermediate layer 30 (e.g., distribution layer) interposed between acquisition layer 20 and composite 130. Similarly, FIGURES 25B and 25C illustrate constructs 190 and 200 having layer 30 intermediate acquisition layer 20 and composites 130 and 140, respectively.

Composites 130 and 140 and constructs 150, 160, 170, 180, 190, and 200 can be incorporated into absorbent articles. Generally, absorbent articles 210, 220, and  
15 230 shown in FIGURES 26A-26C, respectively; absorbent articles 240, 250, and 260 shown in FIGURE 27A-27C, respectively; and absorbent articles 270, 280, and 290 shown in FIGURE 28A-28C, respectively, include liquid pervious facing sheet 22, liquid impervious backing sheet 24, and composites 130, 140, and constructs 150, 160, 170, 180, 190, and 200, respectively. In such absorbent articles, the facing sheet  
20 is joined to the backing sheet.

The following examples are provided for the purposes of illustration, and not limitation.

## EXAMPLES

### Example 1

#### 25 Reticulated Absorbent Composite Formation: Representative Wetlaid Method

This example illustrates a wetlaid method for forming a representative absorbent composite.

A wetlaid composite formed in accordance with the present invention is prepared utilizing standard wetlaid apparatus known to those in the art. A slurry of a  
30 mixture of standard wood pulp fibers and crosslinked pulp fibers (48 and 12 percent by weight, respectively, based on total weight of dried composite) in water having a consistency of about 0.25 to 3 percent is formed. Consistency is defined as the weight percent of fibers present in the slurry, based on the total weight of the slurry. A wet strength agent such as Kymene® (0.5 percent based on total composite weight) is then

added to the fibrous mixture. Finally, absorbent material (40 percent by weight based on total weight of dried composite) is added to the slurry, the slurry is thoroughly mixed, and then distributed onto a wire mesh to form a wet composite. The wet composite is dried to a moisture content of about 9 to about 15 weight percent based on total composite weight to form a representative reticulated absorbent composite.

Absorbent composites having a variety of basis weights can be prepared from the composite formed as described above by pre- or post-drying densification methods known to those in the art.

#### Example 2

##### 10 Reticulated Absorbent Composite Formation: Representative Foam Method

This example illustrates a foam method for forming a representative absorbent composite.

A lab-size Waring blender is filled with 4L of water and pulp fibers are added. The mixture is blended for a short time. Crosslinked cellulose fibers are then added to the pulp fibers and blended for at least one minute to open the crosslinked fibers and effect mixing of the two fibers. The resulting mixture may contain from 0.07 to 12 percent by weight of solids.

The mixture is placed in a container and blended for a few seconds with an air-entrapping blade. A surfactant (Incronan 30, Croda, Inc.) is added to the blended mixture. Approximately 1 g of active surfactant solids per gram of fiber is added. The mixture is blended while slowly raising the mixer blade height from the rising foam. After about one minute, the mixing is terminated, superabsorbent is added, and the mixing is restarted for another one-half minute at constant mixer blade height. The resulting foam-fiber mixture will have a volume about three times the volume of the original mixture.

The mixture is rapidly poured into a sheet mold having an inclined diffusion plate. After the addition of the mixture, the plate is removed from the mold, and a strong vacuum is applied to reduce the foam-fiber height. After most of the visible foam disappears, the vacuum is discontinued and the resulting sheet removed from the mold and passed, along with a forming wire, over a slit couch to remove excess foam and water.

The sheet is then dried in a drying oven to remove the moisture.

### Example 3

#### Acquisition Times for a Representative Reticulated Absorbent Composite

5 In this example, the acquisition time for a representative reticulated absorbent composite formed in accordance with the present invention (Composite A) is compared to a commercially available diaper (Diaper A, Kimberly-Clark).

The tests were conducted on commercially available diapers (Kimberly-Clark) from which the core and surge management layer were removed and the surrounds used. The test diapers were prepared by inserting the absorbent composite into the  
10 diaper.

The aqueous solution used in the tests is a synthetic urine available from National Scientific under the trade name RICCA. The synthetic urine is a saline solution containing 135 meq./L sodium, 8.6 meq./L calcium, 7.7 meq./L magnesium, 1.94% urea by weight (based on total weight), plus other ingredients.

15 A sample of the absorbent structure was prepared for the test by determining the center of the structure's core, measuring 1 inch to the front for liquid application location, and marking the location with an "X". Once the sample was prepared, the test was conducted by first placing the sample on a plastic base (4 3/4 inch x 19 1/4 inch) and then placing a funnel acquisition plate (4 inch x 4 inch plastic plate) on top of the sample with the plate's hole positioned over the "X". A donut weight (1400 g)  
20 was then placed on top of the funnel acquisition plate to which was then attached a funnel (4 inch diameter). Liquid acquisition was then determined by pouring 100 mL synthetic urine into the funnel and measuring the time from when liquid was first introduced into the funnel to the time that liquid disappeared from the bottom of the funnel into the sample. The measured time is the acquisition time for the first liquid  
25 insult. After waiting one minute, a second 100 mL portion was added to the funnel and the acquisition time for the second insult was measured. After waiting an additional one minute, the acquisition was repeated for a third time to provide an acquisition time for the third insult. The acquisition times reported in seconds for  
30 each of the three successive 100 mL liquid insults for Diaper A and Composite A are summarized in Table 1.



Table 1. Acquisition Time Comparison

Insult	Acquisition Time (sec)	
	Diaper A	Composite A
1	45	10
2	60	11
3	75	10

As shown in Table 1, liquid is more rapidly acquired by the absorbent composite than for the commercially available diaper containing an air-laid storage core. The results show that the air-laid core does not acquire liquid nearly as rapidly as the reticulated composite. The commercial diaper also exhibited characteristic diminution of acquisition rate on successive liquid insults. In contrast, the composite formed in accordance with the invention maintained a relatively constant acquisition time as the composite continued to absorb liquid on successive insult. Significantly, the absorbent composite exhibits an acquisition time for the third insult that is substantially less (about fourfold) than that of the commercially available diaper for initial insult. The results reflect the greater wicking ability and capillary network for the wetlaid composite compared to a conventional air-laid storage core in general, and the enhanced performance of the reticulated absorbent composite in particular.

#### Example 4

##### Acquisition Rate and Rewet for Representative Reticulated Absorbent Composites

In this example, the acquisition time and rewet of representative reticulated absorbent composites formed in accordance with the present invention (designated Composites A1-A4) are compared to a commercially available diaper (Diaper A, Kimberly-Clark). Composites A1-A4 differ by the method by which the composites were dried.

Certain properties of the tested composites, including the amount of superabsorbent material (weight percent SAP) in the composite and basis weight for each of the composites, are summarized in Table 2.

The tests were conducted on commercially available diapers (Kimberly-Clark) from which the cores were removed and used as surrounds. The test diapers were prepared by inserting the tested composites into the diapers.

The acquisition time and rewet are determined in accordance with the multiple-dose rewet test described below.

Briefly, the multiple-dose rewet test measures the amount of synthetic urine released from an absorbent structure after each of three liquid applications, and the time required for each of the three liquid doses to wick into the product.

The aqueous solution used in the tests was a synthetic urine available from National Scientific under the trade name RICCA, and as described above in Example 1.

A preweighed sample of the absorbent structure was prepared for the test by determining the center of the structure's core, measuring 1 inch to the front for liquid application location, and marking the location with an "X". A liquid application funnel (minimum 100 mL capacity, 5-7 mL/s flow rate) was placed 4 inches above the surface of the sample at the "X". Once the sample was prepared, the test was conducted as follows. The sample was flattened, nonwoven side up, onto a tabletop under the liquid application funnel. The funnel was filled with a dose (100 mL) of synthetic urine. A dosing ring (5/32 inch stainless steel, 2 inch ID x 3 inch height) was placed onto the "X" marked on the samples. A first dose of synthetic urine was applied within the dosing ring. Using a stopwatch, the liquid acquisition time was recorded in seconds from the time the funnel valve was opened until the liquid wicked into the product from the bottom of the dosing ring. After a twenty-minute wait period, rewet was determined. During the twenty-minute wait period after the first dose was applied, a stack of filter papers (19-22 g, Whatman #3, 11.0 cm or equivalent, that had been exposed to room humidity for minimum of 2 hours before testing) was weighed. The stack of preweighed filter papers was placed on the center of the wetted area. A cylindrical weight (8.9 cm diameter, 9.8 lb.) was placed on top of these filter papers. After two minutes the weight was removed, the filter papers were weighed and the weight change recorded. The procedure was repeated two more times. A second dose of synthetic urine was added to the diaper, and the acquisition time was determined, filter papers were placed on the sample for two minutes, and the weight change determined. For the second dose, the weight of the dry filter papers was 29-32 g, and for the third dose, the weight of the filter papers was 39-42 g. The dry papers from the prior dosage were supplemented with additional dry filter papers.

Liquid acquisition time is reported as the length of time (seconds) necessary for the liquid to be absorbed into the product for each of the three doses. The results are summarized in Table 2.

Rewet is reported as the amount of liquid (grams) absorbed back into the filter papers after each liquid dose (i.e., difference between the weight of wet filter papers and the weight of dry filter papers). The results are also summarized in Table 2.

Table 2. Acquisition Time and Rewet Comparison

5

Composite	SAP % (w/w)	Basis Weight (gsm)	Acquisition Time (sec)			Rewet (g)		
			Insult 1	Insult 2	Insult 3	Insult 1	Insult 2	Insult 3
A1	49.4	568	16	19	26	0.1	0.4	2.4
A2	38.3	648	17	19	22	0.1	0.7	2.5
A3	35.9	687	29	26	27	0.2	0.2	0.7
A4	38.8	672	17	18	21	0.1	0.3	0.9
Commercial air-laid core	40.0	625	34	35	39	0.1	4.0	12.6

As indicated in Table 2, the acquisition times for representative composites formed in accordance with the invention (Composites A1-A4) were significantly less than for the commercially available core.

10 The rewet of the representative composites (Composites A1-A4) is significantly less than for the other cores. While the composites exhibited relatively low rewet initially, after the third insult the commercially available core showed substantial rewet. In contrast, Composites A continued to exhibit low rewet.

#### Example 5

#### 15 Horizontal and Vertical Wicking for a Representative Reticulated Absorbent Composite

In this example, the wicking characteristics of a representative reticulated absorbent composite (Composite A) are compared to a commercially available diaper storage core (Diaper B, Procter & Gamble).

20 The horizontal wicking test measures the time required for liquid to horizontally wick preselected distances. The test was performed by placing a sample composite on a horizontal surface with one end in contact with a liquid bath and measuring the time required for liquid to wick preselected distances. Briefly, a sample

composite strip (40 cm x 10 cm) was cut from a pulp sheet or other source. If the sheet has a machine direction, the cut was made such that the 40 cm length of the strip was parallel to the machine direction. Starting at one end of the 10 cm width of the strip, a first line was marked at 4.5 cm from the strip edge and then consecutive lines at 5 cm intervals were marked along the entire length of the strip (i.e., 0 cm, 5 cm, 10 cm, 15 cm, 20 cm, 25 cm, 30 cm, and 35 cm). A horizontal wicking apparatus having a center trough with level horizontal wings extending away from opposing sides of the trough was prepared. The nonsupported edge of each wing was positioned to be flush with the inside edge of the trough. On each wing's end was placed a plastic extension to support each wing in a level and horizontal position. The trough was then filled with synthetic urine. The sample composite strip was then gently bent at the 4.5 cm mark to form an approximately 45° angle in the strip. The strip was then placed on the wing such that the strip lay horizontally and the bent end of the strip extended into and contacted the liquid in the trough. Liquid wicking was timed beginning from when the liquid reached the first line marked on the composite 5 cm from the 4.5 cm bend. The wicking time was then recorded at 5 cm intervals when 50 percent of the liquid front reached the marked interval (e.g., 5 cm, 10 cm). The liquid level in the trough was maintained at a relatively constant level throughout the test by replenishing with additional synthetic urine. The horizontal wicking results are summarized in Table 3.

Table 3. Horizontal Wicking Comparison

Distance (cm)	Wicking Time (sec)	
	Diaper B	Composite A
5	48	15
10	150	52
15	290	134
20	458	285
25	783	540
30	1703	1117
35	-	1425

The results tabulated above indicate that horizontal wicking is enhanced for the absorbent composite formed in accordance with the invention compared to a conventional air-laid core. The wicking time for Composite A is about 50 percent of that for the conventional diaper core. Thus, the horizontal wicking for Composite A is about 1.5 to about 3 times that of a commercially available storage core.

The vertical wicking test measures the time required for liquid to vertically wick preselected distances. The test was performed by vertically suspending a sample composite with one end of the composite in contact with a liquid bath and measuring the time required for liquid to wick preselected distances. Prior to the test, sample composites (10 cm x 22 cm) were cut and marked with consecutive lines 1 cm, 11 cm, 16 cm, and 21 cm from one of the strip's edges. Preferably, samples were preconditioned for 12 hours at 50 percent relative humidity and 23°C and then stored in sample bags until testing. The sample composite was oriented lengthwise vertically and clamped from its top edge at the 1 cm mark, allowing its bottom edge to contact a bath containing synthetic urine. Timing was commenced once the strip was contacted with the liquid. The time required for 5 percent of the wicking front to reach 5 cm, 10 cm, 15 cm, and 20 cm was then recorded. The vertical wicking results are summarized in Table 4.

Table 4. Vertical Wicking Comparison

Distance (cm)	Wicking Time (sec)	
	Diaper B	Composite A
5	20	6
10	Fell Apart	54
15	-	513
20	-	3780

As for the horizontal wicking results, Composite A had significantly greater vertical wicking compared to the commercial core. The results also show that the composite formed in accordance with the invention has significantly greater wet tensile strength compared to the conventional air-laid composite.

### Example 6

#### Liquid Distribution for a Representative Reticulated Absorbent Composite

In this example, the distribution of liquid in a reticulated absorbent composite (Composite A) is compared to that of two commercially available diapers (Diapers A and B above). The test measures the capacity of a diaper core to distribute acquired liquid. Perfect distribution would have 0% deviation from average. Ideal liquid distribution would result in equal distribution of the applied liquid in each of the four distribution zones (i.e., about 25% liquid in each zone).

Liquid distribution is determined by weighing different zones of a sample that has been subjected to the multiple-dose rewet test described above in Example 4. Basically, after the last rewet, the wings of the diaper are removed and then cut into four equal length distribution zones. Each zone is then weighed to determine the weight of liquid contained in each zone.

The liquid distribution results for a representative reticulated absorbent composite approach ideality. The results indicate that while the representative commercial storage cores accumulate liquid near the site of insult, liquid is efficiently and effectively distributed throughout the reticulated absorbent storage core.

### Example 7

#### Wet and Dry Tensile Strength for a Reticulated Absorbent Composite

In this example, the measurement of wet and dry tensile strength of a representative absorbent composite is described. The wet tensile strength is determined as described below using a 2.5 x 4 inch strip wetted with 0.9% saline at a 10:1 weight ratio of saline:sample. The dry tensile strength is performed as described by TAPPI Method T 494 om-96-T.

A dry pad tensile integrity test is performed on a 4 inch by 4 inch square test pad by clamping a dry test pad along two opposing sides. About 3 inches of pad length is left visible between the clamps. The sample is pulled vertically in an Instron testing machine and the tensile strength measured is reported in N/m. The tensile strength is converted to tensile index, Nm/g, by dividing the tensile strength by the basis weight g/m<sup>2</sup>.

A wet tensile integrity test is performed by taking a sample composite that has been immersed in synthetic urine for 10 minutes and then allowed to drain for 5 minutes and placing the sample in a horizontal jig. Opposite ends of the sample are clamped and then pulled horizontally on the Instron testing machine. The wet tensile

strength, N/m, is converted to tensile index, Nm/g, by dividing the tensile strength by the basis weight g/m<sup>2</sup>.

Typically, increasing the amount of Kymene® from 2 to 100 pounds per ton of fiber may increase the dry tensile strength from about 0.15 Nm/g to 0.66 Nm/g and the wet tensile from about 1.5 Nm/g to about 2.4 Nm/g.

Wet tensile is determined by the following procedure:

Sample:

6.35 cm (2.5 in.) CD x 10.2 cm (4 in.) MD\*

Equipment:

Horizontal Instron

10 Newton Load Cell

Clamp Pressure 20 psi, minimize compromising sample integrity

60 mL syringe

0.9% Blood Bank Saline Solution

Procedure:

1) Weigh sample to the nearest 0.1 gram.

2) Using a syringe, uniformly add 10 times the sample weight of Saline Solution to the topside of the sample.

3) Control the solution delivery so the sample is not damaged.

4) When all the solution has been delivered, start a timer for 5 minutes.

5) After the 5 minutes, clamp the sample in the Instron and test for tensile.

6) Repeat three times for each sample type.

7) Record the average value in b/in.

\*Note: Sample size may be shorter than 10.2 cm as long as the sample is securely held by the end clamps.

#### Example 8

##### Taber Stiffness for Representative Reticulated Absorbent Composites

The stiffness of representative reticulated absorbent composites formed in accordance with the present invention was determined by the Taber Stiffness method. Representative composites were formed by wetlaid and foam methods. These composites included matrix fibers (48 percent by weight, southern pine commercially available from Weyerhaeuser Co. under the designation NB416), resilient fibers

(12 percent by weight, polymaleic acid crosslinked fibers), and absorbent material (40 percent by weight, superabsorbent material commercially available from Stockhausen). One of the wetlaid and one of the foam-formed composites further included a wet strength agent (about 0.5 percent by weight, polyamide-epichlorohydrin resin commercially available from Hercules under the designation Kymene®).

The stiffness of the foam-formed composites was significantly lower than the similarly constituted wetlaid composites. The results also indicate that, for the wetlaid composites, the inclusion of a wet strength agent increases the composite's stiffness.

10

#### Example 9

##### Reticulated Absorbent Composite Formation: Representative Wetlaid Method

This example illustrates a representative wetlaid method for forming a reticulated composite using a Rotoformer papermaking machine.

15 Briefly, slurries of absorbent material and fibers in water were introduced into the Rotoformer's headbox. The fibrous slurry was introduced to the headbox in the conventional manner. The absorbent slurry was introduced through the use of a dispersion unit consisting of a set of spargers. The spargers were fed from a header fed by the absorbent slurry supply. The dispersion unit is mounted on the Rotoformer headbox with the spargers inserted into the headbox fiber stock such that the flow of  
20 the absorbent slurry is against the fiber stock flow. Such a reversed flow for the absorbent slurry is believed to provide more effective mixing of the absorbent material and the fibers than would occur for absorbent material flow in the same direction as the fiber stock.

Absorbent material is introduced into the Rotoformer headbox as a slurry in  
25 water. One method that provides suitable results for introducing absorbent material into the headbox is a mixing system that includes a funnel attached directly to the inlet of a pump into which chilled water is fed at a controlled rate. The funnel receives water and dry absorbent material delivered from absorbent material supply by auger metering and forms a pond that contains absorbent material and water. The absorbent  
30 slurry is preferably pumped from the funnel to the headbox at approximately the same rate as water is delivered to the funnel. Such a system minimizes the exposure of the absorbent to the water. In practice, the absorbent slurry is delivered from the mixing system to the headbox through a 10 to 50 foot conduit in less than about 10 seconds.

In a typical formation run, fiber stock flow to the Rotoformer headbox was  
35 about 90 gpm (gallon/min) and absorbent slurry (1 - 2.6 % solids) flow was about 10



gpm. Prior to initiation of fiber stock flow to the headbox and the introduction of absorbent slurry to the dispersion unit, water was flowed into the dispersion unit to the headbox to prevent fibers from plugging the spargers. Once the target basis weight of fiber was reached, the absorbent auger metering system was initiated and absorbent slurry was introduced into the headbox. For the runs made in accordance with the method described above, the target fiber basis weight was about 370 gsm ( $\text{g/m}^2$ ) and the production speed was about 10 fpm (ft/min). The relatively slow production speed was a consequence of the relatively limited drying capability of the machine's flat-bed dryer.

The headbox contents including fibers and absorbent were deposited on a forming wire and dewatered to provide a wet composite. The wet composite was then dried to a moisture content of from about 9 to about 15 weight percent based on total composite weight to form a representative reticulated absorbent composite.

Absorbent composites having a variety of basis weights can be prepared from the composite formed as described above by pre- or post-drying densification methods known to those in the art.

Examples 10-15 illustrate the formation of representative reticulated absorbent composites using the method described above.

#### Example 10

A representative composite was formed as described in Example 9. The composite included about 60% by weight fibers and about 40% by weight absorbent material based on the total weight of composite. The fiber stock was a mixture of 80% by weight standard wood pulp fibers (once-dried southern pine commercially available from Weyerhaeuser Company under the designation FR416) and 20% by weight crosslinked pulp fibers. The absorbent material was a crosslinked polyacrylate commercially available from Stockhausen under the designation SXM 77, which was screened using 300 micron mesh to eliminate fines prior to use. The composite also included about 25 pounds wet strength agent (a polyacrylamide-epichlorohydrin resin commercially available from Hercules under the designation Kymene® 557LX) per ton of fibers.

Target density of the absorbent composite was accomplished by calendering using a single nip with no applied load.

Performance data for the representative composite formed as described above (Composite B) is presented in Tables 5 and 6 in Example 16.

#### Example 11

A representative composite was formed as described in Example 10 except that the composite was calendered at 25 fpm.

Performance data for the representative composite formed as described above  
5 (Composite C) is presented in Tables 5 and 6 in Example 16.

#### Example 12

A representative composite was formed as described in Example 11 except that the amount of wet strength agent in the composite was reduced to 12.5 pounds per ton fiber and the standard wood pulp fibers were never-dried FR416 fibers.

10 Performance data for the representative composite formed as described above (Composite D) is presented in Tables 5 and 6 in Example 16.

#### Example 13

A representative composite was formed as described in Example 12 except that the composite was not densified.

15 Performance data for the representative composite formed as described above (Composite E) is presented in Tables 5 and 6 in Example 16.

#### Example 14

A representative composite was formed as described in Example 12 except that the wood pulp fibers were once-dried FR416 fibers.

20 Performance data for the representative composite formed as described above (Composite F) is presented in Tables 5 and 6 in Example 16.

#### Example 15

25 A representative composite was formed as described in Example 12 except that the amount of fibers in the composite was increased to about 80% by weight and the amount of absorbent present in the composite was decreased to about 20% by weight of the total composite.

Performance data for the representative composite formed as described above (Composite G) is presented in Tables 5 and 6 in Example 16.

Example 16

The performance of representative composites (Composites B-D) prepared as described in Examples 10-15 is summarized in Tables 5 and 6. The liquid wicking, absorbent capacity, wet and dry tensile strength, and wet strength of the representative composites are compared to a conventional handsheet in Table 5. The conventional handsheet had a basis weight and density comparable to the representative composites and included 60 percent by weight fibers (25 percent crosslinked fibers and 75 percent standard wood pulp fibers), 40 percent by weight superabsorbent material, and 12.5 pounds Kymene per ton fibers. The results presented in Table 5 are the average of three measurements except for the tensile values, which average four measurements. In the table, "MD" refers to the composites' machine direction and "CD" refers to the cross-machine direction. The wicking values were obtained by the methods described in Example 5 and the wet and dry tensile values were obtained by the method described in Example 7. The wet strength value was calculated and is defined as the ratio of wet tensile to dry tensile values. The mass flow rate value (g/min/g) was determined by measuring the weight gain of a portion of a composite (22 cm x 5 cm) divided by the lesser of the time required for the liquid to wick 15 cm or 15 minutes, divided by the weight of the original sample.

Table 5. Performance Characteristics

Composite	Wicking					Capacity 15 Minute Free Swell Cap. (g/g)	Wet Tensile		Dry Tensile		Wet Strength	
	Time to 10 cm (sec)	Time to 15 cm (sec)	Final Wick (cm)	5 Min. (Vert.) Cap. (g/g)	Mass Flow Rate (g/min/g)		MD (g/in)	CD (g/in)	MD (g/in)	CD (g/in)	MD (%)	CD (%)
B	45	234	23	7.6	1.9	20	1585	1222	>480	4385	< 32	< 28
C	47	221	24	8.3	2.3	19	1317	1241	>480	4277	< 27	< 29
D	59	> 400	18	9.3	< 1.4	24	673	488	2940	2455	23	20
E	160	> 400	19	9.4	< 1.4	22	1091	764	>480	3771	< 23	< 20
F	38	144	25	7.7	3.2	15	1654	1291	>520	5100	< 31	< 25
G	52	245	22	8.4	2.1	20	1686	980	>520	4800	< 32	< 21
handsheet	159	> 300	16	10.9	2.2	31	226		0			

The absorbent capacity of several of the representative composites is summarized in Table 6. In this capacity test, portions of the representative composites (i.e., 10 cm squares) were immersed in a 1% saline solution. The samples were allowed to absorb liquid and swell for 10 minutes. The difference in the weight of the composite before and after the 10 minute swell is the capacity that is reported as cc/g.

Table 6. Absorbent capacity

Composite	Capacity (cc/g)
B	16.9
C	16.9
D	20.4
E	21.5

Example 17

The Flexibility and Softness of Representative Reticulated Absorbent

Composites:

Wetlaid Handsheets

The flexibility and softness of representative reticulated absorbent composites formed in accordance with the present invention was determined by an edgewise ring crush method. In the method, a length of the composite (typically about 12 inches) is formed into a cylinder and its ends stapled together to provide cylinder having a height equal to the composite's width (typically about 2.5 inches). Edgewise ring crush is measured by adding mass to the top of the composite ring sufficient to reduce the composite cylinder's height by one-half. The more flexible the composite, the less weight required to reduce the height in the measurement. The edgewise ring crush is measured and reported as a mass (g). Edgewise compression (EC) is the ring crush reported in units of g/gsm in the tables below.

The following is a description of the ring crush method.

Samples: 6.35 cm (2.5 in) X 30.5 cm (12 in)

Triplicate analysis (A, B, C)

Method:

- 1) Cut triplicate of sample size, lengthwise in the composite machine direction (MD).

- 2) Condition samples for 2 hours at 50% relative humidity or ambient conditions.
- 3) With the wire side on the outside, form the individual samples into loops so the two narrow ends meet without any overlap. Using four staples, attached the ends together at the top, bottom, and twice in the middle. The top and bottom staples should be 0.3-0.5 cm from the edge and the middle staples should be less than 2 cm from each other and the respective top or bottom staple. Finally, ensure that each staple penetrates fiber only areas.
- 4) Set the bottom platen on a smooth, level surface.
- 5) Place the sample, edgewise and in the center, between the top and bottom platens.
- 6) Gently place a 100-g weight on the center of the top platen (or 500-weight) and wait 3 seconds.
- 7) Then, gently stack 3 more 100-g weights at 3-second intervals.
- 8) If the ring collapses 50% or more of it's original height within a 3-second interval, then record the total amount of weight necessary to do so, i.e., add the weight of the top platen and the other combined weights.
- 9) If the combined weight doesn't crush the sample, then carefully remove the four 100-g weights.
- 10) Gently add a(nother) 500-g weight and weight 3 seconds.
- 11) If the ring collapses 50% or more of it's original height within a 3-second interval, then record the total amount of weight necessary to do so, i.e., add the weight of the top platen and weight(s).
- 12) Repeat step 6 through 11, increasing the number of 500-g weights by one for each cycle.
- 13) Repeat steps 5 through 11 for the other replicates.
- 14) Record the average weight for the replicates in g•f rounded to the nearest 10 g.

Calculations:

$$\text{Average ring crush weight} = (\text{Weight A} + \text{Weight B} + \text{Weight C})/3$$

Representative composites were formed by wetlaid and foam methods. The representative composites were formed as handsheets using a 20 inch X 20 inch handsheet mold. The target basis weight for the composites was 400 g/m<sup>2</sup>. To increase post-forming consistency to about 20 to 35 percent, five blotters and a

vacuum couch were utilized. To reduce swelling of the absorbent material, ice water was used as the dispersion medium. The composites were dried a 150°C. Unless otherwise noted each composite included a wet strength agent (polyamide-epichlorohydrin resin commercially available from Hercules under the designation Kymene®, 10 lb/ton fiber) and absorbent material (superabsorbent material obtained from Stockhausen, 40 percent by weight based on the total weight of the composite). The composites included various amounts of matrix fibers (southern pine commercially available from Weyerhaeuser Co. under the designation NB416), resilient fibers (crosslinked fibers), synthetic fibers, and other materials as indicated.

10 The compositions of the representative composites that were evaluated for softness by the edgewise ring crush are described below.

Control Composite. A wetlaid composite composed of 40 percent by weight superabsorbent material and 60 percent by weight matrix fibers.

15 Composite 1. A foam-formed composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers.

Composite 2. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers.

20 Composite 3. A wetlaid composite composed of 40 percent by weight superabsorbent material, 15 percent by weight matrix fibers, and 45 percent by weight crosslinked fibers.

Composite 4. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight chemithermomechanical pulp (CTMP). (Svenska Cellulosa Aktiebolaget, Sweden).

Composite 5. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight high porosity fibers (HPZ). (Buckeye Corp., Memphis, TN).

30 Composite 6. A wetlaid composite composed of 60 percent by weight superabsorbent material and 40 percent by weight matrix fibers.

Composite 7. A wetlaid composite composed of 60 percent by weight superabsorbent material, 20 percent by weight matrix fibers, and 20 percent by weight crosslinked fibers.

35 Composite 8-1. A wetlaid composite composed of 40 percent by weight superabsorbent material (large screened SXM-77, 0.05-1.00 mm, SXM-77 available

from Stockhausen), 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers.

5     Composite 8-2. A wetlaid composite composed of 40 percent by weight superabsorbent material (small screened SXM-77, 0.208-0.355), 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers.

Composite 8-3. A wetlaid composite composed of 40 percent by weight superabsorbent material (unscreened SXM-77), 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers.

10    Composite 8-4. A wetlaid composite composed of 40 percent by weight superabsorbent material (large screened superabsorbent, 0.50-1.00 mm), 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers.

Composite 9. A wetlaid composite composed of 40 percent by weight superabsorbent material, 60 percent by weight matrix fibers (NB416) that had been coated with clay (25 percent by weight) (made by Weyerhaeuser and designated T-757).  
15

Composite 10. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers (T-757), and 30 percent by weight crosslinked fibers.

20    Composite 11. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight crosslinked fibers, and 30 percent by weight matrix fibers (NB416) that had been coated with precipitated calcium carbonate (10 percent by weight) (made by Weyerhaeuser and designated MT-10).

25    Composite 12. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight synthetic fibers (PET fibers, straight T-224). (Hoechst Celanese Corp., Charlotte, NC).

Composite 13. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight synthetic fibers (PET fibers, curly T-224).

30    Composite 14. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight cellulose acetate.

35    Composite 15. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers. Surfactant RW-150 (Union Carbide Corporation) was included in the formation process.



Composite 16. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers. Surfactant QS-15 (Union Carbide Corporation) was included in the formation process.

5     Composite 17. A wetlaid composite composed of 40 percent by weight superabsorbent material and 60 percent by weight matrix fibers. A debonding agent, Quaker 224C (Quaker Chemical Corp., Conshohocken, PA), was included in the formation process.

10     Composite 18. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers. A debonding agent, Quaker 224C, was included in the formation process.

15     Composite 19. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers. The composite was formed by partially drying the web to about 70 percent consistency, conveying the web through an "S" configuration around two narrow diameter (1 inch) rolls followed by complete drying.

20     Composite 20. A wetlaid composite composed of 40 percent by weight superabsorbent material, 30 percent by weight matrix fibers, and 30 percent by weight crosslinked fibers. The composite was treated with ethanol prior to drying to displace water in the composite.

A summary of the compositions of the representative composites is summarized in Table 7.

Table 7. Representative Absorbent Composite Composition

25

	Superabsorbent Material	Matrix Fiber (%)	Crosslinked Fiber (%)	Other Material (%)	
Control	40	60			
1	40	30	30		Foam formed
2	40	30	30		
3	40	15	45		
4	40	30		30	CTMP
5	40	30		30	HPZ
6	60	40			
7	60	20	20		

	Superabsorbent Material	Matrix Fiber (%)	Crosslinked Fiber (%)	Other Material (%)	
8-1	40	30	30		Large SXM-77
8-2	40	30	30		Small SXM-77
8-3	40	30	30		SXM-77
8-4	40	30	30		Large screened superabsorbent material
9	40			60	T-757
10	40		30	30	T-757
11	40		30	30	PCC-10
12	40	30		30	T-224-straight
13	40	30		30	T-224-curly
14	40	30		30	Cellulose acetate
15	40	30	30		Amphoteric
16	40	30	30		Sulphated
17	40	60			Debondor
18	40	30	30		Debondor
19	40	30	30		Mechanical
20	40	30	30		Ethanol

Edgewise ring crush values (g) and edgewise compression values (g/gsm) of representative composites are summarized in Table 8. The values in Table 8 represent the average of three measurements. The ring crush values were determined for 30.5 cm X 6.35 cm composite sheets.

5 Table 8. Representative Composite Edgewise Ring Crush and Edgewise Compression

Composite	Weight (g)	Caliper (mm)	Basis Weight (g/m <sup>2</sup> )	Density (g/cm <sup>3</sup> )	Edgewise Ring Crush (g)	Edgewise Compression (g/gsm)
CONTROL	9.42	3.92	487	0.12	6300	12.9
1	7.98	3.75	412	0.11	2400	5.8
2	9.63	4.84	498	0.10	2333	4.7
3	8.61	5.43	445	0.08	850	1.9
4	9.51	3.68	492	0.13	3900	7.9

Composite	Weight (g)	Caliper (mm)	Basis Weight (g/m <sup>2</sup> )	Density (g/cm <sup>3</sup> )	Edgewise Ring Crush (g)	Edgewise Compression (g/gsm)
5	7.05	3.61	364	0.10	3300	9.1
6	10.30	2.74	532	0.19	3667	6.9
7	9.42	3.92	487	0.12	1133	2.3
8-1	8.81	4.35	455	0.10	2867	6.3
8-2	8.41	4.42	435	0.10	2967	6.8
8-3	7.61	4.28	393	0.09	2267	5.8
8-4	9.40	5.14	486	0.09	2467	5.1
9	8.40	2.47	434	0.18	12833	29.6
10	8.70	3.91	449	0.12	6100	13.6
11	8.74	5.11	452	0.09	1600	3.5
12	9.35	4.43	483	0.11	1700	3.5
13	9.15	7.09	473	0.07	1800	3.8
14	6.65	3.23	343	0.11	1733	5.0
15	10.01	4.72	517	0.11	2167	4.2
16	8.55	3.95	442	0.11	2367	5.4
17	8.33	2.36	431	0.18	2767	6.4
18	8.75	4.19	452	0.11	1367	3.0
19	9.43	5.09	487	0.10	1933	4.0
20	9.07	5.49	468	0.09	1400	3.0

The results demonstrate that composite flexibility and softness, as measured by the edgewise ring crush and edgewise compression, can be adjusted and controlled by optimizing the composite's components and their amounts. Generally, increasing the percentage of matrix fiber in a composite decreases its softness, and conversely, increasing the percentage of either crosslinked fiber or superabsorbent material in a composite results in increased softness.

The presence of crosslinked fiber in a composite increases its flexibility and softness. For example, Control Composite includes no crosslinked fiber and has a edgewise compression value of 12.9 g/gsm. Composite 2, in which 50 percent of its fibrous content is crosslinked fiber, has a edgewise compression value of 5.8 g/gsm. Increasing the amount of crosslinked fiber relative to matrix fiber further increases

flexibility and softness. Composite 3, in which 67 percent of its fibrous content is crosslinked fiber, has an edgewise compression value of 1.9 g/gsm.

Replacing the crosslinked fiber in the composite with other materials such as CTMP (Composite 4) or HPZ (Composite 5) results in increased ring crush values and reduced flexibility and softness. Replacing the composite's crosslinked fiber with additional superabsorbent material (Composite 6) also decreases flexibility and softness. However, increasing the amount of superabsorbent material and maintaining a relatively high proportion (about 50 percent by weight based on total weight of fibers) of crosslinked fiber provides a composite (Composite 7) having increased flexibility and softness compared a representative wetlaid composite (Composite 2). Substituting cellulose acetate for crosslinked fiber (Composite 14) also resulted in a composite having increased flexibility and softness compared a representative wetlaid composite (Composite 2).

Replacing the matrix fiber in the composite with other fibers such as calcium carbonate coated fiber (Composite 11) and synthetic (PET) fiber (Composites 12 and 13) resulted in composites having increased flexibility and softness. The addition of a debonding agent also increased the composite's flexibility and softness.

Mechanical and chemical treatments of composites also increased composite flexibility and softness. These effects are shown by comparing the ring crush values of Composite 2 to Composites 19 and 21, respectively.

No relationship appears to exist between either ring crush and basis weight or ring crush and density for the composites evaluated.

The flexibility and softness of the composites of the invention can be dramatically increased by increasing the amount of superabsorbent material and crosslinked fiber in the composite. The flexibility and softness of representative composites composed of superabsorbent (40, 50 and 60 percent by weight), crosslinked fiber (10, 15, 25, 30, and 45 percent by weight), and matrix fiber (10, 15, 25, 30, and 45 percent by weight) is summarized in Table 9. In Table 9, superabsorbent A refers to a superabsorbent obtained from Stockhausen and superabsorbent B refers to a superabsorbent obtained from Stockhausen under the designation SXM-77.

**Table 9. Representative Composite Edgewise Ring Crush and Compression:  
Effect of Superabsorbent and Crosslinked Fiber**

Composite	Superabsorbent Material Type	Superabsorbent Material (%)	Crosslinked Fiber (%)	Matrix Fiber (%)	Basis Wt. Target (g/m <sup>2</sup> )	Edgewise Ring Crush (g)	Edgewise Compression (g/gsm)
21	A	40	45	15	500	1430	2.9
22	A	40	15	45	500	8220	16.4
23	A	60	30	10	400	430	1.1
24	A	60	10	30	400	2000	5.0
25	B	40	45	15	500	1500	3.0
26	B	40	15	45	500	8220	16.4
27	B	60	30	10	400	570	1.4
28	B	60	10	30	400	2100	5.3
29	A	50	25	25	450	2070	4.6
30	B	50	25	25	450	2270	5.0

Referring to Table 9, at constant superabsorbent material percentage (40 percent by weight), decreasing the amount of crosslinked fiber from 45 percent to 15 percent and increasing the matrix fiber from 15 percent to 45 percent dramatically reduces flexibility and softness. Comparing Composites 21 and 25 to Composites 22 and 26, respectively, the edgewise compression increases more than about 5-fold (from 2.9 to 16.4 g/gsm and from 3.0 to 16.4 g/gsm). Maintaining the proportion of crosslinked to matrix fibers at 3:1 and increasing the amount of superabsorbent material to 60 percent by weight further significantly increases flexibility and softness. Comparing Composites 21 and 25 to Composites 23 and 27, respectively, the edgewise compression value decreases more than about 2-fold (from 2.9 to 1.1 g/gsm and from 3.0 to 1.4 g/gsm). Increasing the amount of superabsorbent material to 60 percent from 40 percent provides for increased flexibility and softness even for composites in which the proportion of crosslinked to matrix fiber is 1:3. Comparing Composites 24 and 28 to Composites 22 and 26, respectively, the edgewise compression value decreases about 3-fold (from 16.4 to 5.0 g/gsm and from 16.4 to 5.3 g/gsm).

The results demonstrate that for these representative composites replacing matrix fibers with either crosslinked fiber or superabsorbent material decreases ring

crush and edgewise compression and improves flexibility and softness. The correlation between ring crush and percentage matrix fiber is presented graphically in FIGURE 29. Referring to FIGURE 29, ring crush increases dramatically as the percentage of matrix fiber increases.

#### Example 18

##### The Flexibility and Softness of Representative Reticulated Absorbent Composites:

##### Foam-Formed Sheets

The flexibility and softness of representative reticulated absorbent composites formed by a foam-forming method in accordance with the present invention was determined by the an edgewise ring crush and edgewise compression methods. Representative composites were formed as described in above using a twin-wire former and included 70 percent by weight superabsorbent material and 30 percent by weight fibers. The first composites included 50 percent by weight matrix fibers (NB416) and 50 percent by weight crosslinked fibers based on the total weight of fibers. The second composites included 30 percent by weight matrix fibers (NB416) and 70 percent by weight crosslinked fibers based on the total weight of fibers. Both composites included a wet strength agent (polyamide-epichlorohydrin resin, 10 lb/ton fiber) and had surface strata composed of matrix fibers (NB416, 40 percent by weight) and crosslinked fibers (60 percent by weight). The first composites had an average edgewise compression value of about 2.9 g/gsm and the second composites had an average edgewise compression value of about 1.1 g/gsm. The results demonstrate that for these high superabsorbent-containing composites increasing the amount of crosslinked fibers significantly reduces edgewise compression and improves flexibility and softness. For these composites containing 70 percent by weight superabsorbent, increasing the percentage of crosslinked fiber in the fibrous component from 50 percent to 70 percent decrease ring crush and compression and increased flexibility and softness by about 2.5-fold.

#### Example 19

##### The Softness and Wet Integrity of Representative Reticulated Absorbent Composites:

##### Edgewise Compression

The softness and wet integrity of representative reticulated absorbent composites formed by wetlaid and foam-forming methods in accordance with the present invention was determined by the edgewise compression. Edgewise compression is discussed in The Handbook of Physical and Mechanical Testing of Paper and Paperboard, Richard E. Mark, Dekker 1983 (Vol. 1). As noted above,

edgewise compression (EC) is an indication of the softness of a dried absorbent composite.

Representative composites were formed as described above using a twin-wire former and included 40 percent by weight superabsorbent material and 60 percent by weight fibers. The first composites included 80 percent by weight matrix fibers (NB416) and 20 percent by weight crosslinked fibers based on the total weight of fibers. The second composites included 40 or 60 percent by weight matrix fibers (NB416) and 60 or 40 percent by weight crosslinked fibers based on the total weight of fibers. Certain of the composites included a wet strength agent (polyamide-epichlorohydrin resin). Referring to Table 10, Composites 31-34 are wetlaid composites and Composites 35-39 are foam-formed composites. Several of the composites were further treated by, for example, calendering, after formation.

The EC values for the representative composites is summarized in Table 10. The values presented in the table represent the average value of three repetitions.

Table 10. Representative Composite Edgewise Compression

Composite	Post- Formation Treatment	Superabsorbent Material (%)	Crosslinked Fiber (%)	Matrix Fiber (%)	Wet Strength Agent (lb/ton)	Basis Wt.	Ring Crush (g)	EC Value (g/gsm)
31	--	40	12	48	20	392	4300	10.8
32	channeled	40	12	48	20	421	1800	4.3
33	--	40	12	48	20	386	4200	11
34	channeled	40	12	48	20	342	1200	3.5
35	calendered	40	24	36	none	399	2100	5.3
36	grooved	40	36	24	10	330	200	0.8
37	--	40	36	24	10	316	790	2.5
38	--	40	12	48	20	367	3100	8.4
39	calendered	40	12	48	20	339	900	2.7
40	--	40	30	30*	--	384	880	2.3
41	calendered	40	30	30*	--	369	780	2.1
42	calendered	40	30	30*	--	266	360	1.4
43	--	40	30	30*	--	277	440	1.6

\*Synthetic fiber blend: 20% PET 224 and 10% T-105



The results demonstrate that the foam-formed composites are generally more flexible and softer than comparably constituted wetlaid composites. Referring to Table 10, wetlaid Composites 31 and 33 had EC values of 10.8 and 11 g/gsm, respectively, while foam-formed Composite 38 had an EC value of 8.4 g/gsm.

5 The effect of crosslinked fiber content on composite flexibility and softness is demonstrated by comparing the ring crush and EC values for Composites 37 and 38. Composite 38 (40:12:48) includes about 20 percent by weight crosslinked fiber based on the total weight of fibers and has an EC value of 8.4. Composite 37 (40:36:24) includes about 60 percent by weight crosslinked fiber based on the total weight of  
10 fibers and has an EC value of 2.8. As noted above, increasing the amount of crosslinked fiber significantly increases composite flexibility and softness. In this example, increasing the crosslinked fiber:matrix fiber ratio from 1:4 to 3:2, resulted in a 3-fold increase in flexibility softness.

Post-formation mechanical treatment (e.g., channeling or calendering) of the  
15 composites increased the composites' flexibility and softness by more than 2-fold, reducing the EC value from 10.8 to 4.3 for Composites 31 and 32, from 11 to 3.5 for Composites 32 and 33, and from 8.4 to 2.7 for Composites 38 and 39. For these composites, post-formation treatment did not significantly adversely affect the composites' wet integrity.

20 Composites 40 - 43 are foam-formed composites in which the matrix fiber (i.e., southern pine) is replaced with a synthetic fiber blend consisting of 20% by weight polyethylene terephthalate fibers (PET 224) and 10% by weight synthetic thermobondable binder fiber (Celbond® T-105).

#### Example 20

#### 25 The Effect of Superabsorbent Polymer Particle Size on Composite Flexibility and Softness

The effect of superabsorbent polymer particle size on the flexibility and softness of representative composites of the invention is described. Representative composites were formed as described above using a foam-forming twin-wire method.  
30 The composites included 60% by weight superabsorbent particles, 20% by weight matrix fibers (southern pine, NB416), and 20% crosslinked fiber. The composites also included a wet strength agent (polyamide-epichlorohydrin resin, 10 lb/ton fiber). The superabsorbent polymer particles incorporated into the representative composites included lightly crosslinked polyacrylates: (1) superabsorbent A obtained from  
35 Stockhausen; (2) SXM77; and (3) screened SXM77 having particle diameter in the range of from about 0.5 to about 1.0 mm.

The measured ring crush, saturation capacity (oven dried), tensile strength, wicking, and basis weights for the representative composites 43-45 are summarized in Table 11. Composite 43-45 included the components described above and superabsorbent polymer particles A, SXM77, and screened SXM77, respectively.

Table 11. The Effect of Superabsorbent Polymer Particle Size on the Properties of Representative Composites

Composite	Saturation Capacity			Ring Crush and Tensile					Unrestrained Vertical Wicking			
	Basis Weight (gsm)	Density (g/cm <sup>3</sup> )	SatCap (g/g)	Basis Weight (gsm)	Density (g/cm <sup>3</sup> )	Edgewise Crush (g)	Edgewise Compression (g/gsm)	Tensile (g/in)	Basis Weight (gsm)	Density (g/cm <sup>3</sup> )	Height at 15 min. (cm)	Wetted Zone Capacity (g/g)
43	380	0.24	21.1	419	0.37	1025	2.4	813	510	0.33	11.6	18.2
44	376	0.20	22.7	403	0.46	2094	5.2	1520	486	0.27	13.1	17.6
45	356	0.18	25.1	401	0.48	1267	3.2	744	477	0.25	12.5	19.0

Referring to Table 11, the results demonstrate that the composite incorporating screened superabsorbent polymer particles having a diameter in the range of from about 0.5 to about 1.0 mm had an edgewise compression value of 3.2 g/gsm compared to 5.2 g/gsm for the similarly formed composite including the corresponding unscreened superabsorbent polymer particles. The edgewise compression value for the composite incorporating the screened superabsorbent polymer particles was about 1.6-fold less than for the corresponding composite indicating its increased flexibility and softness.

The composite incorporating the screened superabsorbent particles also had an increase in saturation capacity of about 10% compared to the composite incorporating unscreened superabsorbent particles.

#### Example 21

#### The Tensile Strength of Representative Reticulated Absorbent Composites: Wetlaid Handsheets

The tensile strength of representative reticulated absorbent composites formed in accordance with the present invention was determined by the dry tensile strength method described in TAPPI Method T 494 om-96-T.

Representative composites were formed as described above in Example 17. Edgewise compression and dry tensile strength of representative composites are summarized in Table 12. In the table, the control composite is composed of superabsorbent particles (40% by weight) and matrix fibers (60% by weight, southern pine), and Composite 2 is composed of superabsorbent particles (40% by weight), matrix fibers (30% by weight, southern pine), and crosslinked fibers (30% by weight).

Table 12. Representative Composite Dry Tensile

Composite	EC Value (g/gsm)	Dry Tensile (g/in)
Control	12.9	3206
1	5.8	919
2	4.7	744
3	1.9	235
4	7.9	1366
5	9.1	1310
6	6.9	1837

Composite	EC Value (g/gsm)	Dry Tensile (g/in)
7	2.3	386
8-1	6.3	870
8-2	6.8	837
8-3	5.8	740
8-4	5.1	793
9	29.6	4769
10	13.6	1873
11	3.5	600
12	3.5	692
13	3.8	761
14	5.0	1200
15	4.2	686
16	5.4	548
17	6.4	1090
18	3.0	293
19	4.0	689
20	3.0	496

The correlation between composite edgewise compression and dry tensile is presented graphically in FIGURE 30. Referring to FIGURE 30, edgewise compression increases dramatically as dry tensile increases. Generally, as tensile strength increases, composite flexibility and softness decreases. Although there appears to be no correlation between composite basis weight and dry tensile, there is some correlation between composite density and dry tensile.

#### Example 22

#### Absorbent Properties of Representative Reticulated Absorbent Composites: Foam-Formed Composites

Representative composites were prepared by foam-forming methods in accordance with the methods described above. The composites included absorbent material (from about 35 to about 45 percent by weight superabsorbent particles based on the total weight of the composite), crosslinked cellulosic fiber, and matrix fibers

(weight ratio of crosslinked fibers to matrix fibers, 1:1). The compositions and physical properties of representative composites (Composites 46-48) are summarized in Table 13.

Table 13. Representative Reticulated Absorbent Composites

5

Composite	OD BW g/m <sup>2</sup>	As is Density g/cm <sup>3</sup>	OD Capacity g/cm <sup>2</sup>	Crotch Softness gr	SAP Content %	Total XL Content % Fiber	Strata BW g/m <sup>2</sup>	Strata XL Content % Fiber
46	411.2	0.14	0.72	427	35	50	50	50
47	508.5	0.19	0.97	536	45	50	50	50
48	498.3	0.20	0.96	563	45	50	50	50

The absorbent properties of these representative composites were determined by measuring (1) unrestrained vertical wicking height; (2) acquisition rate and rewet; (3) saddle acquisition rate; (4) saddle acquisition wicking distribution; and (5) saddle acquisition wicking height.

10

Unrestrained Vertical Wicking Height. The unrestrained vertical wicking height at 15 minutes was measured for the above-identified composites (i.e., unsoftened Composites 43-45) and the corresponding calendered composites as described below.

Material:

15

Synthetic urine for wicking - "Blood Bank" 0.9% Saline Solution

Samples:

Size: 6.5cm(CD) x 25cm(MD), marked with both permanent and water permeable lines at 1, 11, 16, and 21cm along MD.

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Method:

- 1) Perform % Solids on sample material and record.
- 2) Cut Sample and record (as is) weight and dry caliper.
- 3) Clamp sample at 1 cm from top.
- 4) Dip into liquid up to the 1 cm line.
- 5) Immediately start timing.

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- 6) At the end of 5, 10, and 15 minutes, record the Wicking Height by measuring down from the next highest line. Report the wicking height to the nearest 0.5 cm.
- 7) At 15 minutes raise sample out of fluid and while still clamped, cut sample at the 1 cm and 15 cm height lines. Discard the 1 cm section.
- 8) Weigh wet 15 cm long sample and record.
- 9) Unclamp remaining sample and add to balance in order to record entire pad wet weight.
- 10) Report Total Wick Height at 15 minutes.
- 11) Report As-is and O.D. basis Entire Pad Capacity(g/g) by calculating:

$$\text{Entire Pad Capacity(g/g)} = \frac{\text{Wet Wt.-(As Is or O.D. Wt.)}^*}{\text{As-Is or O.D. Wt.}^*}$$

$$^*\text{Pad weight(-1cm section)} = (\text{Total sample weight} \times 0.96)$$

- 15) Calculate the Wicked Pad Capacity if needed:

$$\text{Wicked Pad Capacity} = \text{Entire Pad Capacity} \times \frac{24}{\text{Wicking Ht at 15 min}}$$

The results are summarized in Table 14.

Table 14. Unrestrained Vertical Wicking Height

Composite	Calendered Height (cm)	Density (g/cm <sup>3</sup> )	Uncalendered Height (cm)	Density (g/cm <sup>3</sup> )
46	10.7	0.15	15.2	0.18
47	11.5	0.19	14.7	0.23
48	11.3	0.2	14	0.20

The results indicate that wicking height is reduced by calendering. The result also suggests that calendering disrupts the fibrous network leading to effective wicking throughout the composite.

Acquisition Rate and Rewet. The acquisition rate and rewet of the representative composites was determined by the methods described above in Example 4. In addition to measuring the acquisition rate for three liquid insults and

rewet for Composite 48, the acquisition rate and rewet for Composites 47 and 48 combined with a pledget was also determined. For these constructs, the pledget acts as an acquisition/distribution layer. The results are summarized in Table 15.

Table 15. Acquisition Rate and Rewet (ml/sec)

Composite	1st Insult	2nd Insult	3rd Insult	Final Rewet (g)
47/pledget	2.73	2.53	2.26	15.81
48	2.60	2.12	1.92	18.71
48/pledget	2.65	2.39	2.15	14.65

The results show that the acquisition rate decreases slightly in subsequent insults and that the addition of a pledget slightly decreases acquisition rate. However, the rewet measured for constructs that include a pledget is less than the rewet for constructs that do not include the pledget.

Saddle Acquisition Rate, Distribution, and Wicking Height. Saddle wicking, including acquisition rate, distribution, and wicking height, was determined by the method described below.

**Procedure:**

- 1) Run in triplicate.
- 2) Perform % solids on material. Cut sample to 43cm x (6.5cm-11cm (will vary with sample)).
- 3) Measure (as is) weight and caliper of sample. Calculate Basis weight and density.
- 4) Draw and label the 12 cells using a template and a permanent marker.
- 5) Construct Diaper via instructions on Service Request. (This may result in replacing certain diaper components (i.e., Core) with the sample)).
- 6) Position diaper in Saddle Device so that the "X" is squarely at the bottom of the apparatus and then position the funnel approximately 1 cm directly above the "X."
- 7) Measure out 75ml of Synthetic Urine (Blood Bank 0.9% Saline) and pour into funnel.
- 8) Open the funnel and start the timer. Measure the time at which all of the fluid has left the funnel to the point where the fluid is absorbed into the sample. Record as SWAT.



- 9) At the end of 20 min, 40 min, and 60 min, repeat steps 7 and 8.
- 10) When the timer has reached 80 min, pull out diaper and cut sample into designated cells.
- 11) Pull apart and weigh each cell and record the weight.
- 12) If requested perform wet calipers.

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The saddle acquisition rate results for Composite 45 combined with a pledget are compared to a control composite (removed from Supreme Diaper, commercially available from Kimberly-Clark, Neenah, WI) and are summarized in Table 16.

Table 16. Saddle Acquisition Rate (ml/sec)

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Composite	1st Insult	2nd Insult	3rd Insult
48/pledget	28.05	28.01	31.50
Control	37.77	52.30	53.06

The results indicate that the acquisition rate generally increased with subsequent insults and that the acquisition rate for the construct including Composite 48 and a pledget was less than the rate for the commercially available core.

The saddle acquisition distribution results for Composite 48 combined with a pledget are compared to a control composite and are summarized in Table 17.

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Table 17. Saddle Acquisition Distribution (g/g)

Zone	45/pledget	Control
1	0	0
2	3.73	2.06
3	11.88	9.28
4	13.01	12.40
5	12.16	10.66
6	10.62	9.44
7	3.73	3.91
8	0	0

The results show that the representative composite has relatively effective distribution of acquired liquid throughout the composite.

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The saddle acquisition wicking height results for Composite 48 combined with a pledget are compared to a control composite and are summarized in Table 18.

Table 18. Saddle Acquisition Wicking Height (cm)

Composite	10 min	15 min	20 min	30 min	40 min	50 min	60 min
48/pledget	8.3	8.3	8.3	9.2	9.7	13.2	13.5
Control	8.5	8.5	8.5	9.3	9.5	12.9	13.4

The results indicate that the construct including Composite 45 and pledget have wicking heights comparable to the control composite (removed from Supreme  
5 Core, commercially available from Kimberly-Clark, Neenah, WI).

While the preferred embodiment of the invention has been illustrated and described, it will be appreciated that various changes can be made therein without departing from the spirit and scope of this invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An absorbent composite comprising a reticulated core and a first fibrous stratum, the core and stratum being integrally formed;  
wherein the stratum is coextensive with an outward surface of the core,  
wherein the core comprises a fibrous matrix and absorbent material,  
wherein the fibrous matrix defines voids and passages between voids distributed substantially throughout the matrix,  
wherein the absorbent material is located within some of the voids; and  
wherein the absorbent material located within the voids is expandable into the voids.
2. The composite of Claim 1 wherein the fibrous matrix comprises fibers selected from the group consisting of resilient fibers, matrix fibers, and mixtures thereof.
3. The composite of Claim 2 wherein the resilient fibers are selected from the group consisting of chemically stiffened fibers, anfractuous fibers, chemithermomechanical pulp fiber, prehydrolyzed kraft pulp fibers, synthetic fibers, and mixtures thereof.
4. The composite of Claim 3 wherein the chemically stiffened fibers comprise crosslinked cellulosic fibers.
5. The composite of Claim 3 wherein the synthetic fibers are selected from the group consisting of polyolefin, polyester, and polyamide fibers.
6. The composite of Claim 6 wherein the polyester fibers are polyethylene terephthalate fibers.
7. The composite of Claim 1 wherein the matrix fibers comprise cellulosic fibers.
8. The composite of Claim 2 wherein the resilient fibers are present in the composite in an amount from about 5 to about 60 percent by weight of the total composite.

9. The composite of Claim 2 wherein the matrix fibers are present in the composite in an amount from about 10 to about 60 percent by weight of the total composite.
10. The composite of Claim 1 wherein the absorbent material is a superabsorbent material.
11. The composite of Claim 1 wherein the absorbent material is present in an amount from about 5 to about 60 percent by weight of the total composite.
12. The composite of Claim 1 further comprising a wet strength agent.
13. The composite of Claim 12 wherein the wet strength agent is a resin selected from the group consisting of polyamide-epichlorohydrin and polyacrylamide resins.
14. The composite of Claim 12 wherein the wet strength agent is present in the composite in an amount from about 0.01 to about 2 percent by weight of the total composite.
15. The composite of Claim 1 wherein the composite is formed by a wetlaid process.
16. The composite of Claim 1 wherein the composite is formed by a foam process.
17. The composite of Claim 1 further comprising a second stratum coextensive with the outward surface of the core opposing the first stratum.
18. The composite of Claim 1 wherein the core and stratum are formed from the same fiber furnish.
19. The composite of Claim 1 wherein the core and stratum are formed from different fiber furnishes.
20. The composite of Claim 17 wherein the first and second strata are formed from the same fiber furnish.

21. The composite of Claim 17 wherein the first and second strata are formed from different fiber furnishes.

22. The composite of Claim 1 wherein the core has a basis weight that is different from the basis weight of the stratum.

23. The composite of Claim 17 wherein the first stratum has a basis weight that is different from the basis weight of the second stratum.

24. The composite of Claim 17 wherein the first and second strata have the same basis weight.

25. An absorbent article incorporating the composite of Claim 1.

26. The absorbent article of Claim 25 wherein the article is at least one of a diaper, a feminine care product, and an adult incontinence product.

27. An absorbent article incorporating the composite of Claim 17.

28. The absorbent article of Claim 27 wherein the article is at least one of a diaper, a feminine care product, and an adult incontinence product.

29. An absorbent article comprising an absorbent composite having a reticulated core and a fibrous stratum, the core and stratum being integrally formed, wherein the stratum is coextensive with an outward surface of the core, wherein the core comprises a fibrous matrix and absorbent material, wherein the fibrous matrix defines voids and passages between voids distributed substantially throughout the matrix; wherein the absorbent material is located within some of the voids; and wherein the absorbent material located within the voids is expandable into the voids.

30. The absorbent article of Claim 29 wherein the composite further comprises a second stratum coextensive with the outward surface of the core opposing the fibrous stratum.

31. An absorbent article comprising:  
liquid pervious topsheet;

a storage layer comprising an absorbent composite having a reticulated core and a fibrous stratum, the core and stratum being integrally formed,  
wherein the stratum is coextensive with an outward surface of the core,  
wherein the core comprises a fibrous matrix and absorbent material,  
wherein the fibrous matrix defines voids and passages between voids distributed substantially throughout the matrix;  
wherein the absorbent material is located within some of the voids; and  
wherein the absorbent material located within the voids is expandable into the voids; and  
a liquid impervious back sheet.

32. The absorbent article of Claim 31 wherein the composite further comprises a second stratum coextensive with the outward surface of the core opposing the fibrous stratum.

33. An absorbent article comprising:  
a liquid pervious topsheet;  
an acquisition layer for rapidly acquiring and distributing liquid;  
a storage layer comprising an absorbent composite having a reticulated core and a fibrous stratum, the core and stratum being integrally formed,  
wherein the stratum is coextensive with an outward surface of the core,  
wherein the core comprises a fibrous matrix and absorbent material,  
wherein the fibrous matrix defines voids and passages between voids distributed substantially throughout the matrix;  
wherein the absorbent material is located within some of the voids; and  
wherein the absorbent material located within the voids is expandable into the voids; and  
a liquid impervious back sheet.

34. The absorbent article of Claim 33 wherein the composite further comprises a second stratum coextensive with the outward surface of the core opposing the fibrous stratum.

35. An absorbent article comprising:  
a liquid pervious topsheet;  
an acquisition layer for rapidly acquiring and distributing liquid;

a storage layer comprising an absorbent composite having a reticulated core and a fibrous stratum, the core and stratum being integrally formed, wherein the stratum is coextensive with an outward surface of the core, wherein the core comprises a fibrous matrix and absorbent material, wherein the fibrous matrix defines voids and passages between voids distributed substantially throughout the matrix; wherein the absorbent material is located within some of the voids; and wherein the absorbent material located within the voids is expandable into the voids; an intermediate layer interposed between the acquisition layer and the storage layer; and a liquid impervious back sheet.

36. The absorbent article of Claim 35 wherein the composite further comprises a second stratum coextensive with the outward surface of the core opposing the fibrous stratum.

37. The absorbent article of Claim 33 further comprising leg gathers.

38. A method for forming an absorbent composite, comprising the steps of:

combining resilient fibers, matrix fibers, and absorbent material in a dispersion medium to form a fibrous slurry;

depositing the fibrous slurry on a foraminous support to form a wet composite; withdrawing water from the deposited slurry to provide a web composite having a fibrous stratum formed adjacent the support; and

drying the wet composite to form an absorbent composite having a reticulated core and a fibrous stratum, the core and stratum being integrally formed,

wherein the stratum is coextensive with an outward surface of the core,

wherein the core comprises a fibrous matrix and absorbent material,

wherein the fibrous matrix defines voids and passages between voids distributed substantially throughout the matrix;

wherein the absorbent material is located within some of the voids; and

wherein the absorbent material located within the voids is expandable into the voids.

39. The method of Claim 38 wherein the resilient fibers comprise crosslinked cellulosic fibers.

40. The method of Claim 38 wherein the matrix fibers comprise wood pulp fibers.

41. The method of Claim 38 wherein the absorbent material comprises a superabsorbent material.

42. The method of Claim 38 wherein the fibrous slurry further comprises a wet strength agent.

43. The method of Claim 42 wherein the wet strength agent is a polyamide-epichlorohydrin resin.

44. The method of Claim 38 wherein the method is a wetlaid method.

45. The method of Claim 38 wherein the method is a foam method.

46. The method of Claim 38 wherein the composite further comprises a second stratum coextensive with the outward surface of the core opposing the fibrous stratum.

47. A method for forming an absorbent composite, comprising the steps of:

combining resilient fibers and matrix fibers in a first dispersion medium to form a first fibrous slurry;

combining absorbent material with a second dispersion medium to form an absorbent material slurry;

combining the absorbent material slurry with the first fibrous slurry to provide a second fibrous slurry;

depositing the second fibrous slurry on a foraminous support; withdrawing water from the deposited slurry to provide a wet composite having a fibrous stratum formed adjacent the support; and

drying the wet composite to form an absorbent composite having a reticulated core and a fibrous stratum, the core and stratum being integrally formed,

wherein the stratum is coextensive with an outward surface of the core,

wherein the core comprises a fibrous matrix and absorbent material,



wherein the fibrous matrix defines voids and passages between voids distributed substantially throughout the matrix;

wherein the absorbent material is located within some of the voids; and

wherein the absorbent material located within the voids is expandable into the voids.

48. The method of Claim 47 wherein the first fibrous slurry further comprises a wet strength agent.

49. The method of Claim 47 wherein the composite further comprises a second fibrous stratum coextensive with the outward surface of the core opposing the first stratum.

50. A method for forming a fibrous web, comprising the steps of:

(a) forming a first foam slurry comprising fibers and a surfactant in an aqueous dispersion medium;

(b) forming a second foam slurry comprising fibers and a surfactant in an aqueous dispersion medium;

(c) moving a first foraminous element in a first path;

(d) moving a second foraminous element in a second path;

(e) passing the first foam slurry into contact with the first foraminous element moving in the first path;

(f) passing the second foam slurry into contact with the second foraminous element moving in the second path;

(g) passing a third material between the first and second foam slurries, wherein the third material does not contact the foraminous elements; and

(h) withdrawing foam and liquid from the first and second foam slurries and third material through the first and second foraminous elements to provide a fibrous web.

51. The method of Claim 50 wherein the fibers are selected from the group consisting of resilient fibers, matrix fibers, synthetic fibers, and mixtures thereof.

52. The method of Claim 50 wherein the fibers comprise crosslinked cellulosic fibers and wood pulp fibers.

53. The method of Claim 50 wherein at least one of the first and second foam slurries further comprises a wet strength agent.

54. The method of Claim 50 wherein the third material comprises absorbent material.

55. The method of Claim 50 wherein the third material comprises an aqueous suspension of superabsorbent material.

56. The method of Claim 50 wherein the third material comprises a fibrous slurry.

57. The method of Claim 50 wherein the first foam slurry is different from the second foam slurry.

58. The method of Claim 50 wherein the first and second paths are substantially vertical.

59. The method of Claim 50 practiced in a twin-wire former.

60. The method of Claim 50 wherein the twin-wire former is a vertical downflow former.

61. The method of Claim 50 wherein the step of passing a third material between the first and second foam slurries step comprises passing the third material between the first and second foam slurries after the first and second foam slurries have contacted the first and second foraminous elements, respectively, and withdrawing foam and liquid therefrom.

62. The method of Claim 50 further comprising the step of drying the wet composite to provide an absorbent composite.

63. The method of Claim 50 wherein the step of passing a third material between the first and second foam slurries step comprises passing the third material between the first and second foam slurries after the first and second foam slurries have contacted the first and second foraminous elements, respectively, and withdrawing foam and liquid therefrom.

64. An absorbent composite comprising absorbent material in a fibrous matrix, wherein the composite has an edgewise ring crush value in the range from about 400 to about 1600 grams/inch and a basis weight in the range from about 250 to about 650 gsm.

65. The composite of Claim 64, wherein the absorbent material is present in an amount from about 5 to about 60 percent by weight based on the total weight of the composite.

66. The composite of Claim 64, wherein the fibrous matrix comprises crosslinked cellulosic fibers in an amount from about 5 to about 60 percent by weight based on the total weight of the composite.

67. The composite of Claim 64, wherein the fibrous matrix comprises matrix fibers in an amount from about 10 to about 60 percent by weight based on the total weight of the composite.

68. The composite of Claim 64, wherein the absorbent material is present in about 60 percent by weight based on the total weight of the composite, wherein the fibrous matrix comprises crosslinked fibers present in about 30 percent by weight based on the total weight of the composite and matrix fibers present in about 10 percent by weight based on the total weight of the composite.

69. The composite of Claim 64, wherein the absorbent material is present in an amount from about 40 to about 80 percent by weight based on the total weight of the composite.

70. The composite of Claim 64, wherein the fibrous matrix comprises crosslinked cellulosic fibers in an amount from about 10 to about 50 percent by weight based on the total weight of the composite.

71. The composite of Claim 64, wherein the fibrous matrix comprises matrix fibers in an amount from about 5 to about 30 percent by weight based on the total weight of the composite.

72. An absorbent composite comprising absorbent material in a fibrous matrix,

wherein the absorbent material is present in the composite in an amount from about 40 to about 80 percent by weight based on the total weight of the composite;

wherein the fibrous matrix comprises crosslinked cellulosic fibers and matrix fibers;

wherein the weight ratio of crosslinked fibers to matrix fibers is at least about 3:1; and

wherein the composite has an edgewise ring crush value in the range from about 400 to about 1600 grams/inch.

73. An absorbent composite comprising absorbent material in a fibrous matrix,

wherein the absorbent material is present in the composite in an amount from about 60 to about 80 percent by weight based on the total weight of the composite;

wherein the fibrous matrix comprises crosslinked cellulosic fibers and matrix fibers;

wherein the weight ratio of crosslinked fibers to matrix fibers is at least about 1:1; and

wherein the composite has an edgewise ring crush value in the range from about 400 to about 1600 grams/inch.

74. The composite of Claim 73, wherein the weight ratio of crosslinked fibers to matrix fibers is at least about 2:1.

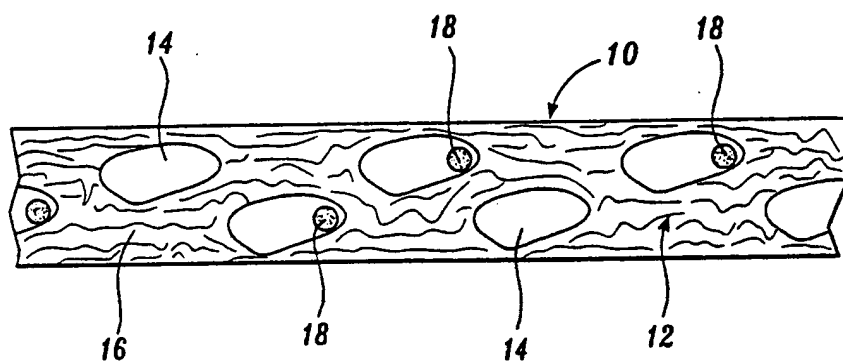
75. The composite of Claim 73, wherein the weight ratio of crosslinked fibers to matrix fibers is at least about 3:1.

76. An absorbent article incorporating the composite of Claim 64 or Claim 72 or Claim 73.

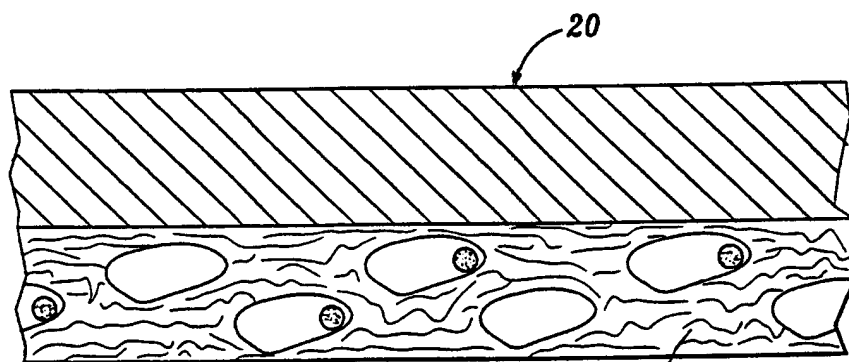
77. The absorbent article of Claim 80, wherein the article is at least one of a diaper, a feminine care product, and an adult incontinence product.

78. An absorbent composite comprising absorbent material in a fibrous matrix, wherein the composite has an edgewise ring crush value in the range from about 400 to about 1600 grams/inch, a basis weight in the range from about 250 to about 650 gsm, and a dry tensile strength in the range from about 50 to about 800 g/inch.

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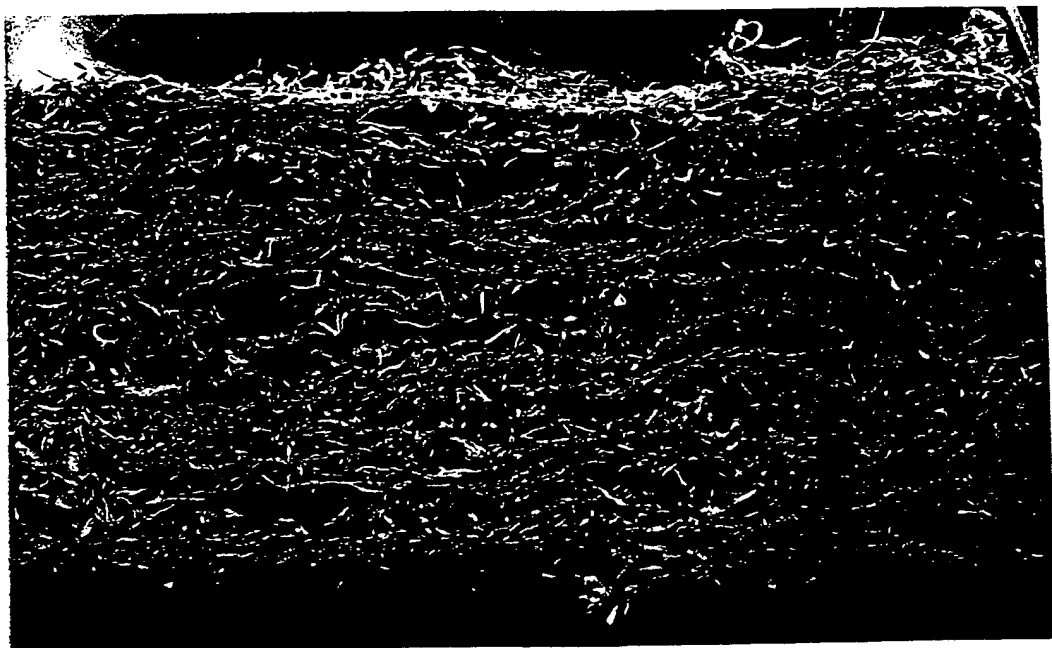


*Fig. 1.*

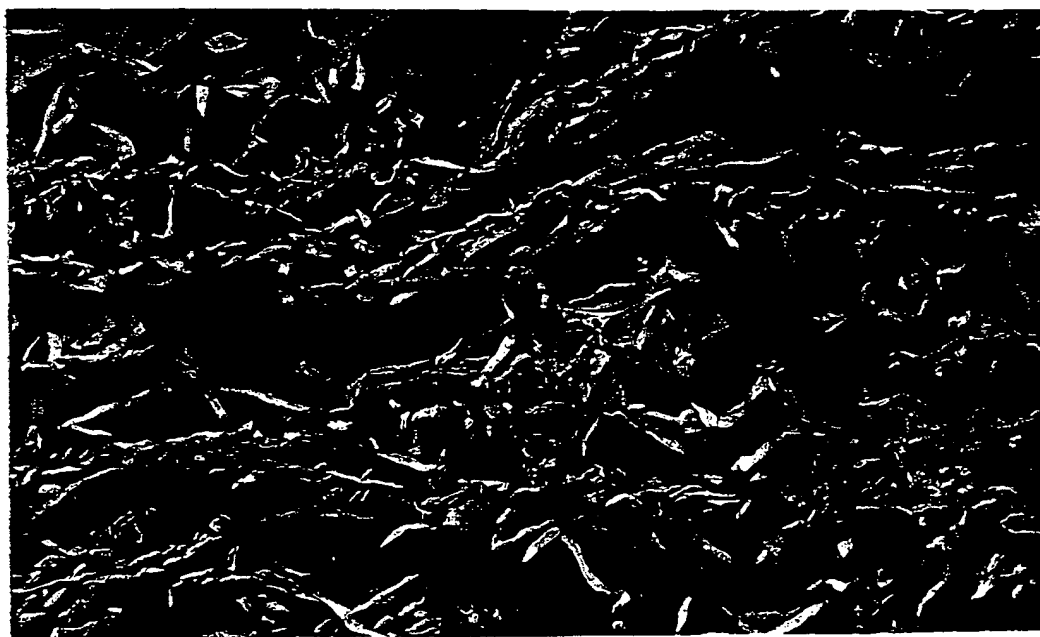


*Fig. 10.*<sup>10</sup>

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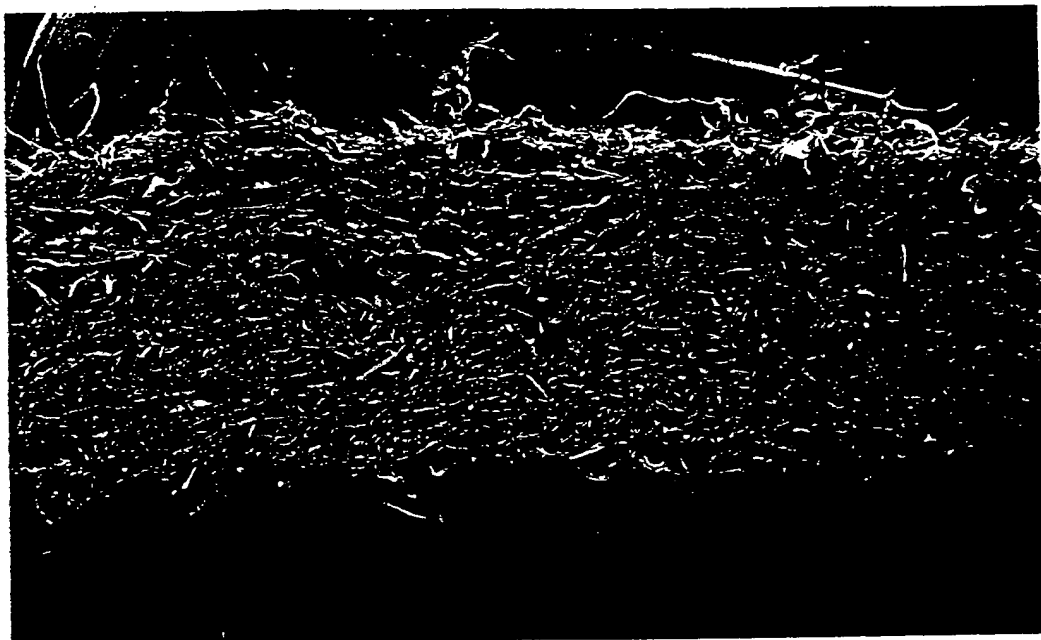


*Fig. 2.*

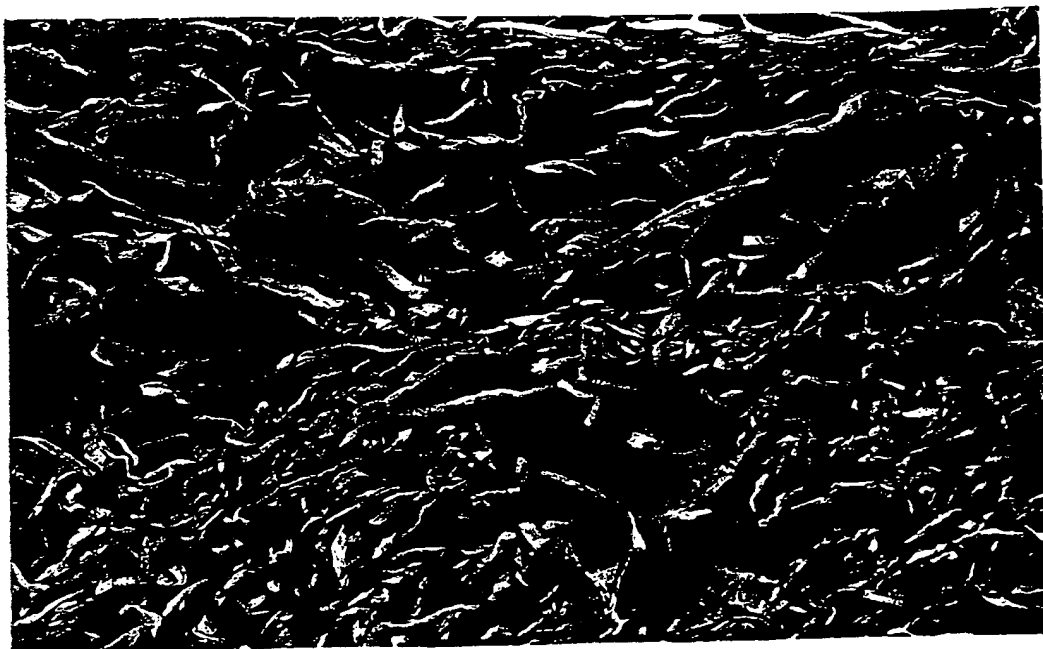


*Fig. 3.*

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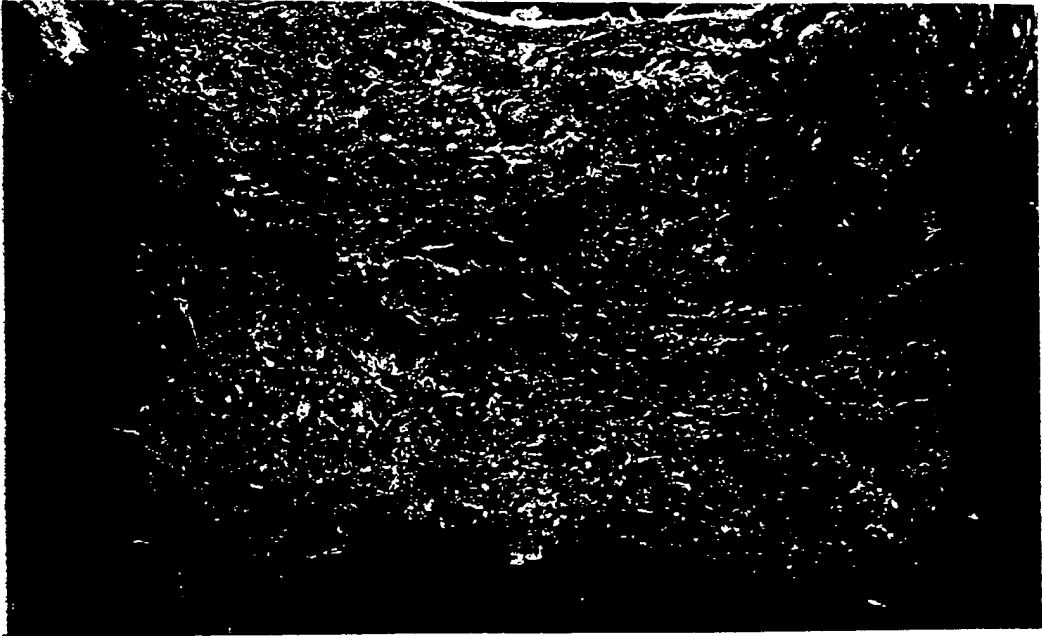
*Fig. 4.*



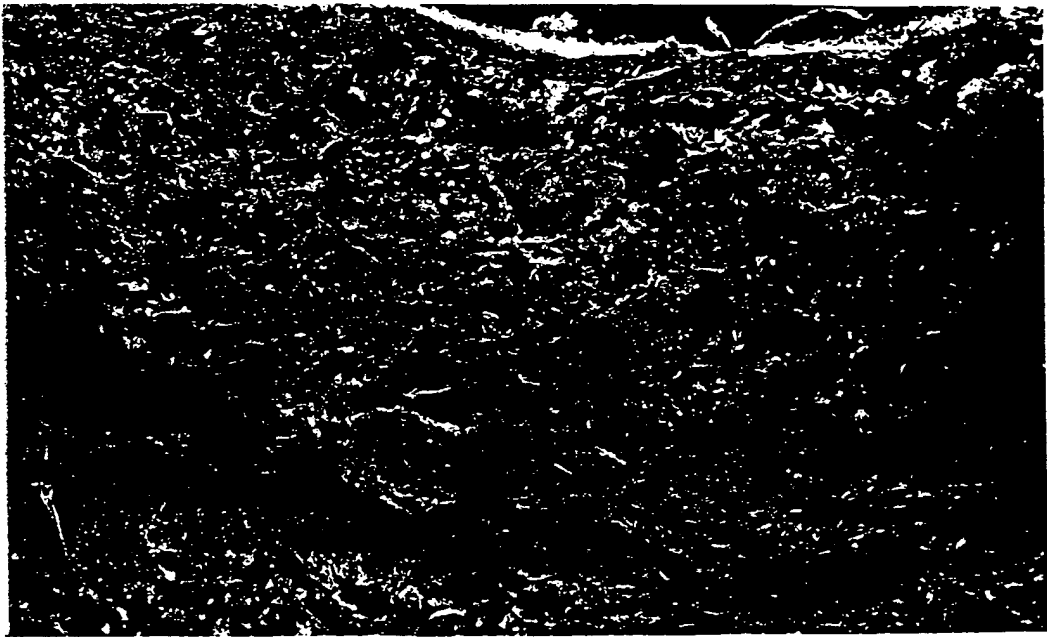
*Fig. 5.*



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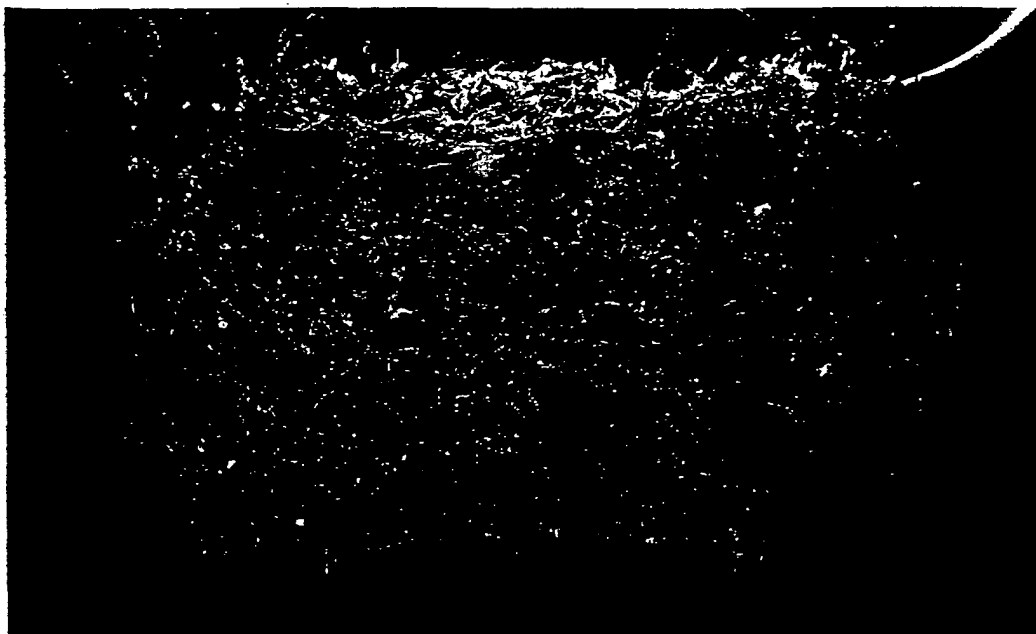


*Fig. 6.*

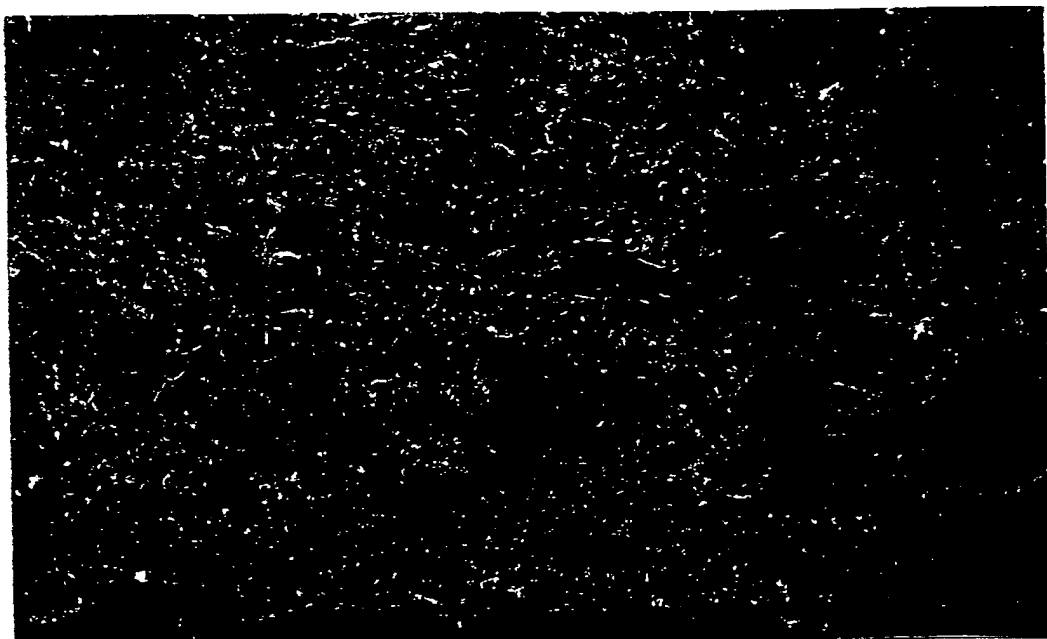


*Fig. 7.*

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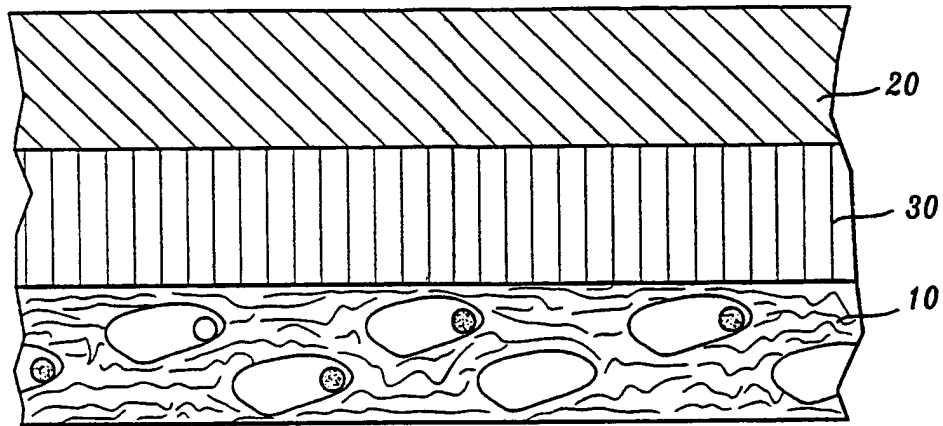


*Fig. 8.*

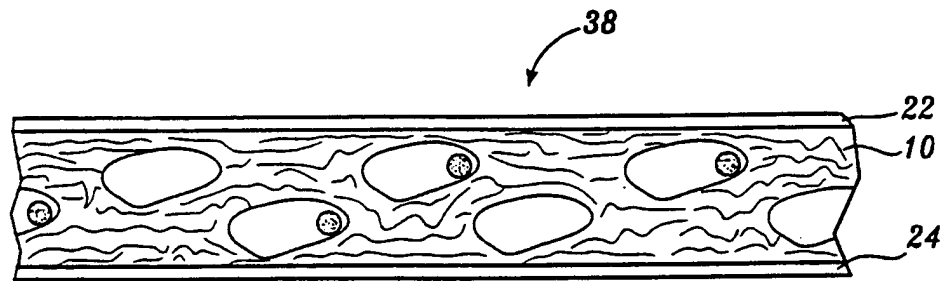


*Fig. 9.*

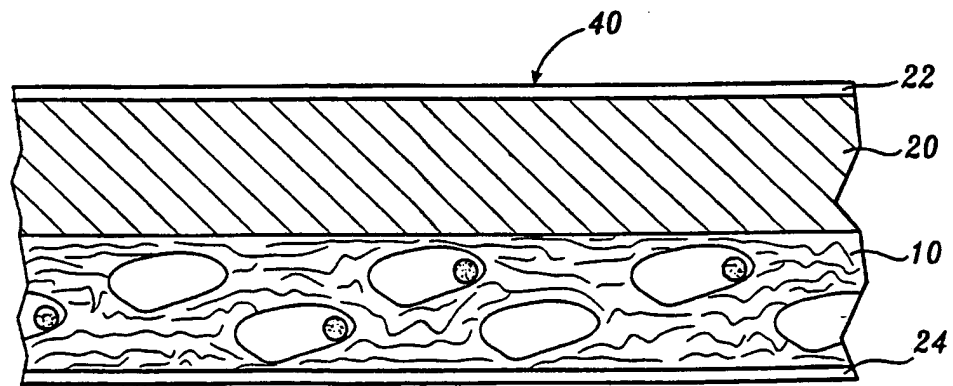
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*Fig. 11.*

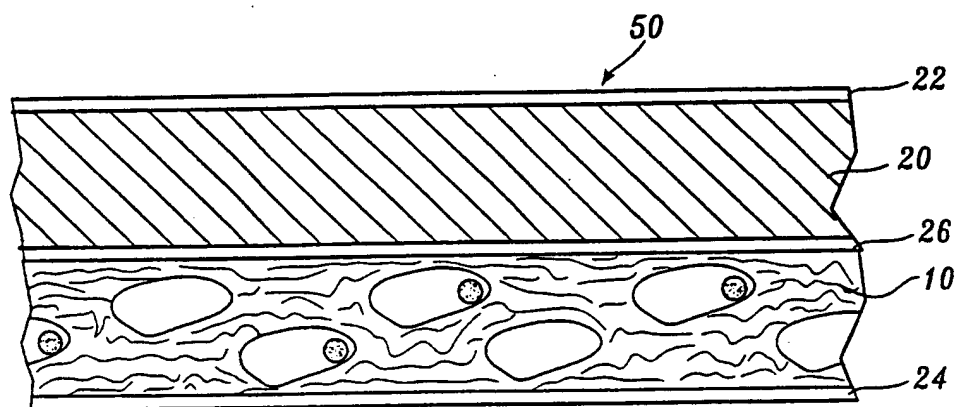


*Fig. 12A.*

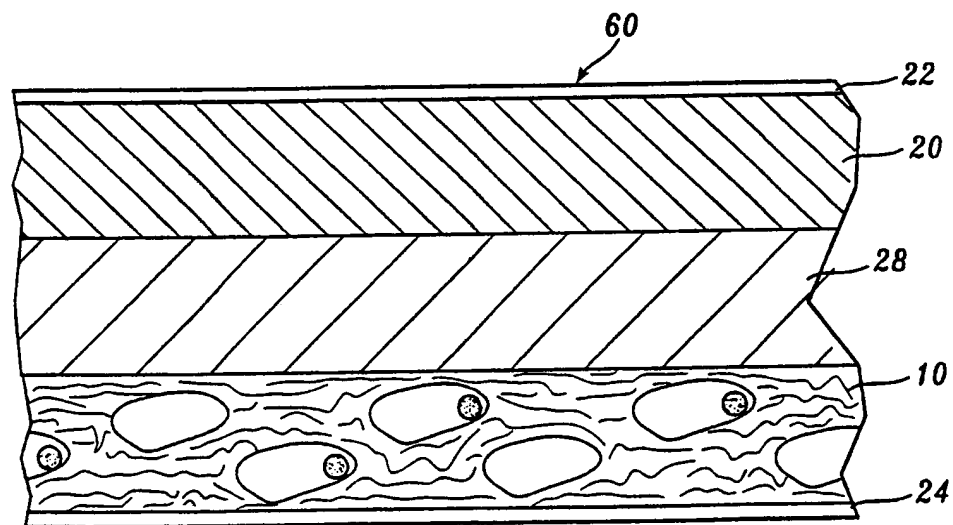


*Fig. 12B.*

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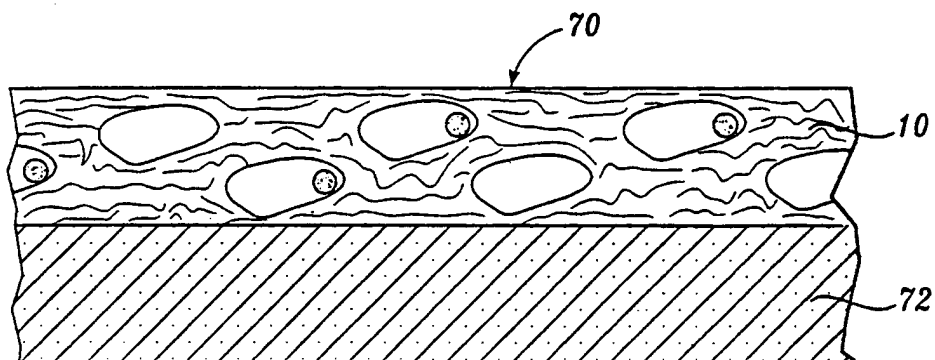


*Fig. 13.*

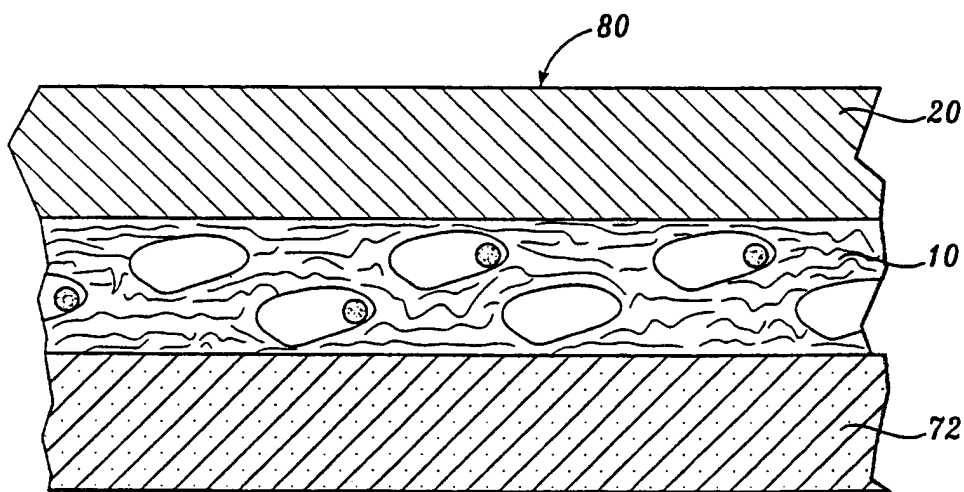


*Fig. 14.*

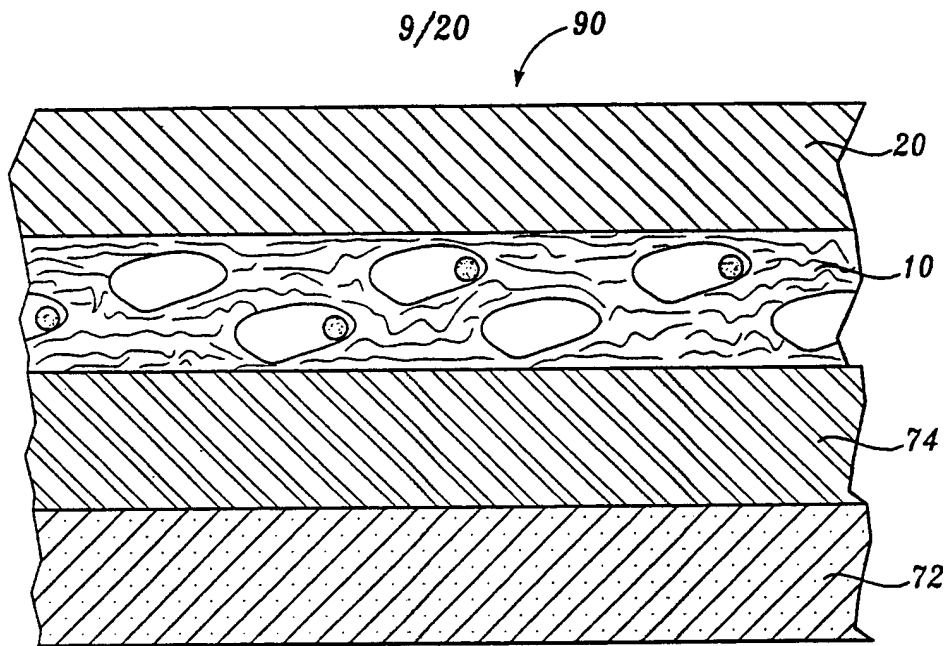
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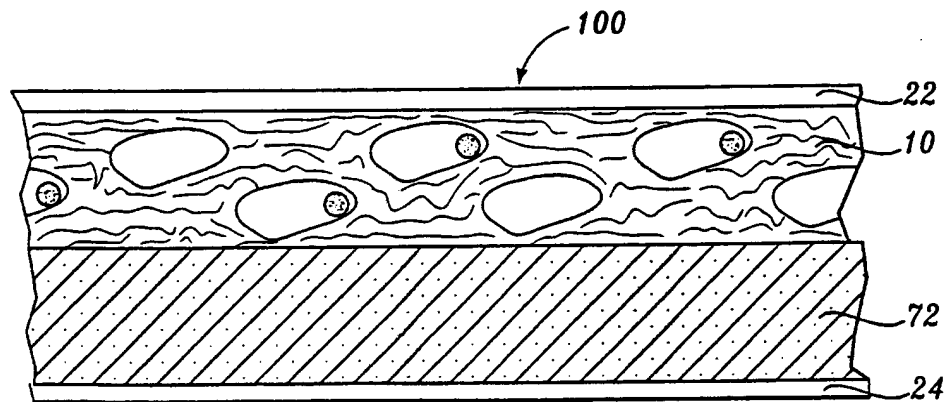
*Fig. 15.*



*Fig. 16.*

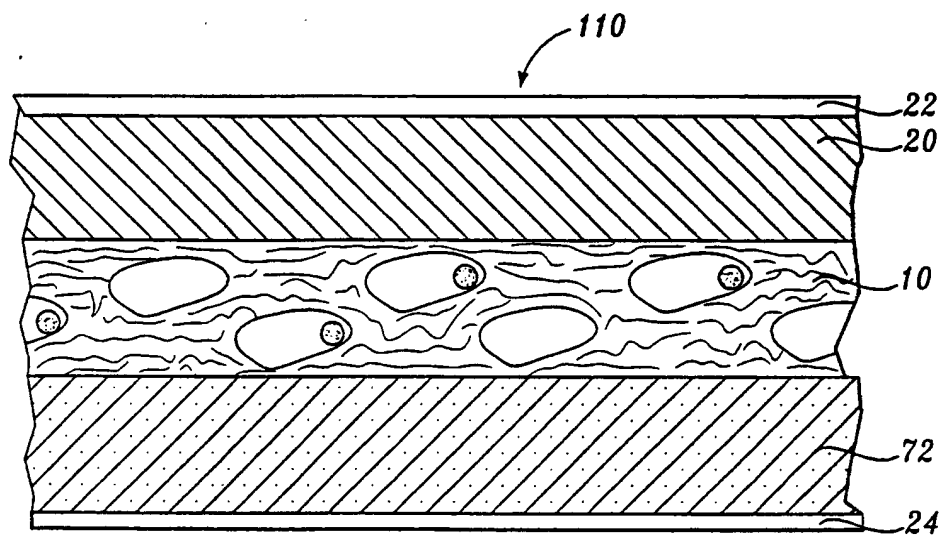
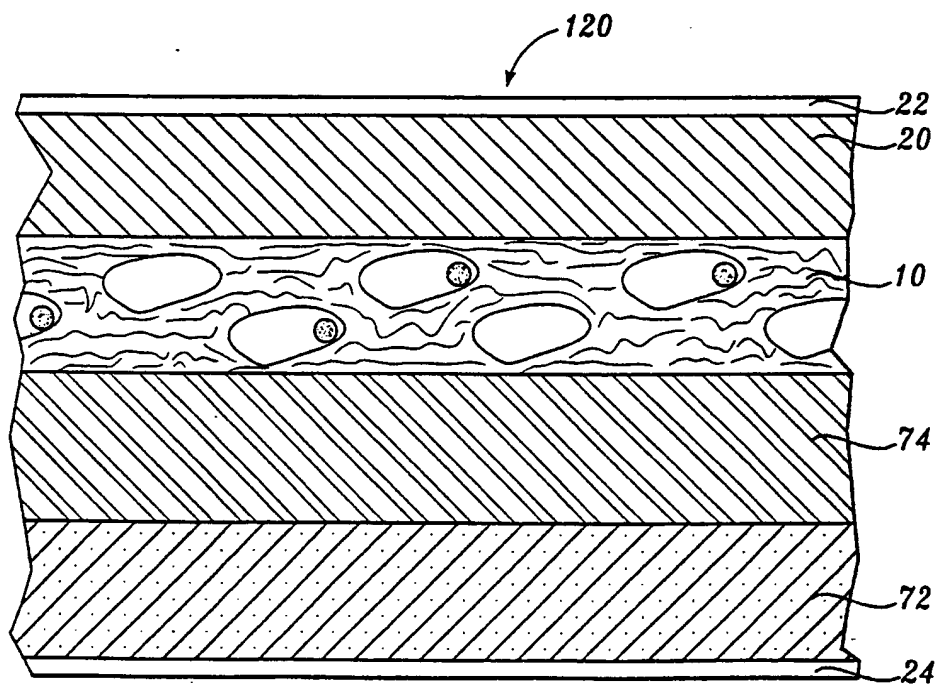


*Fig. 17.*

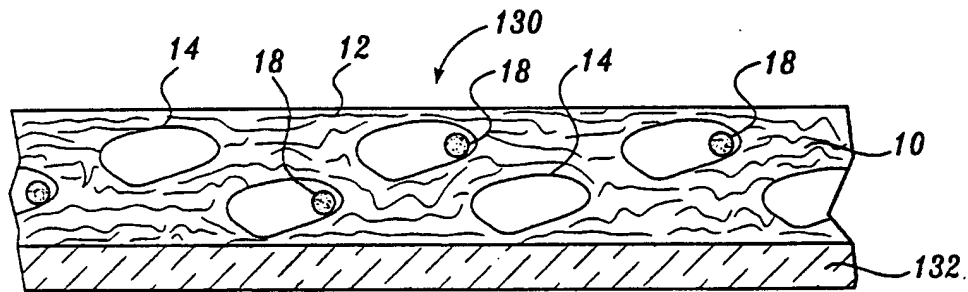


*Fig. 18.*

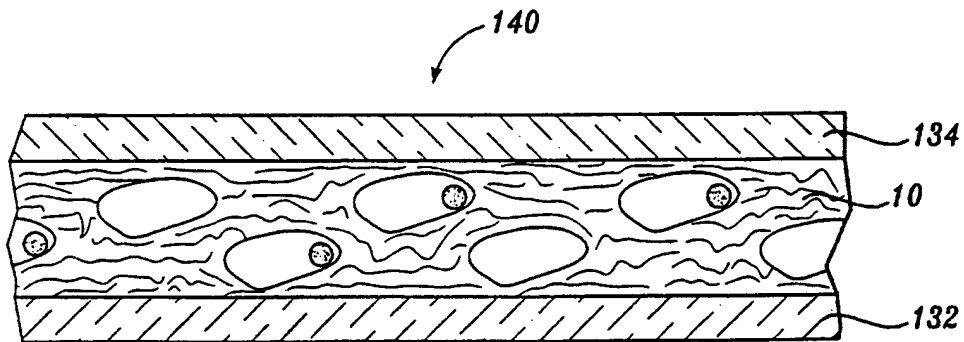
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*Fig. 19.**Fig. 20.*

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*Fig. 21 A.*



*Fig. 21 B.*



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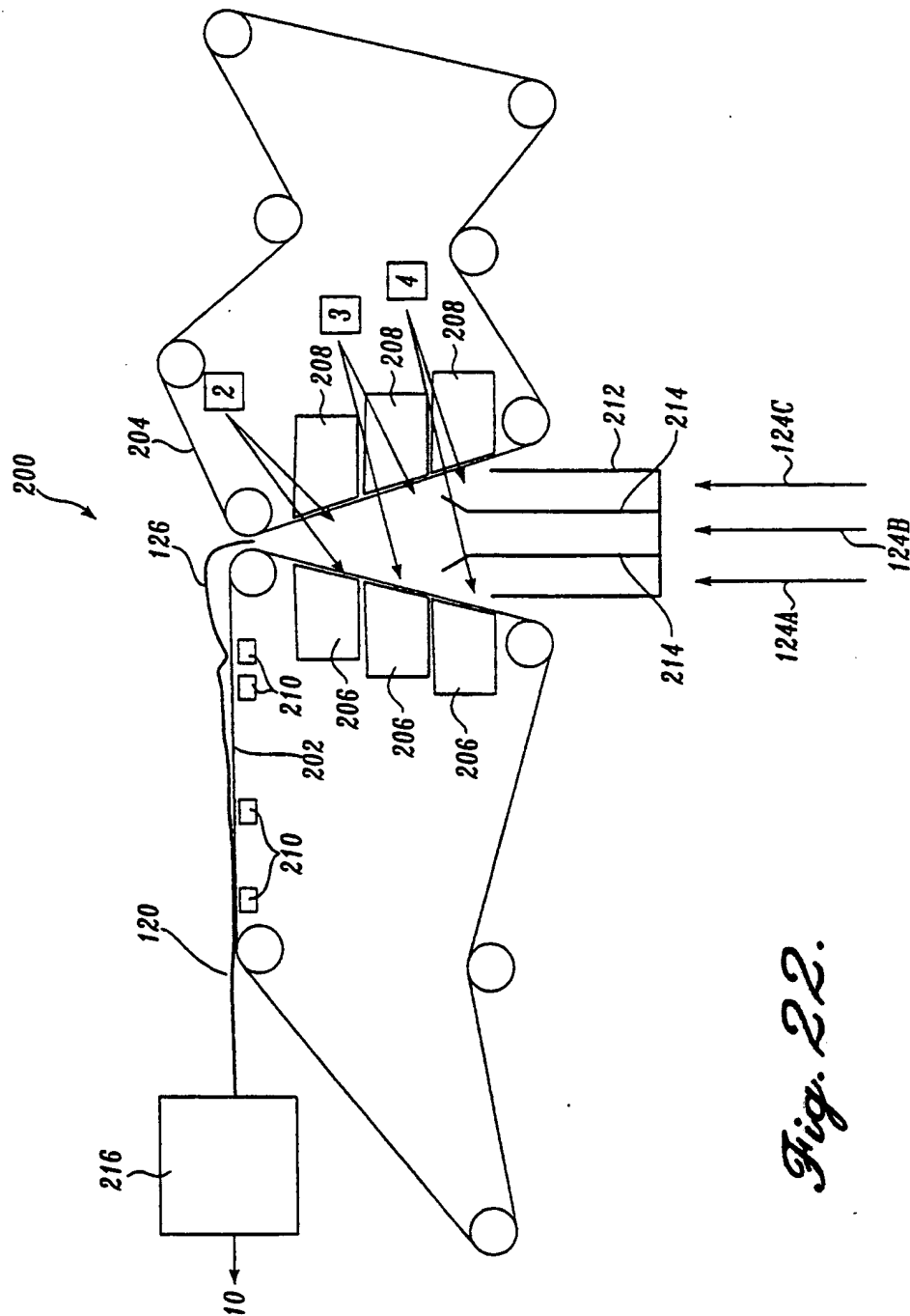
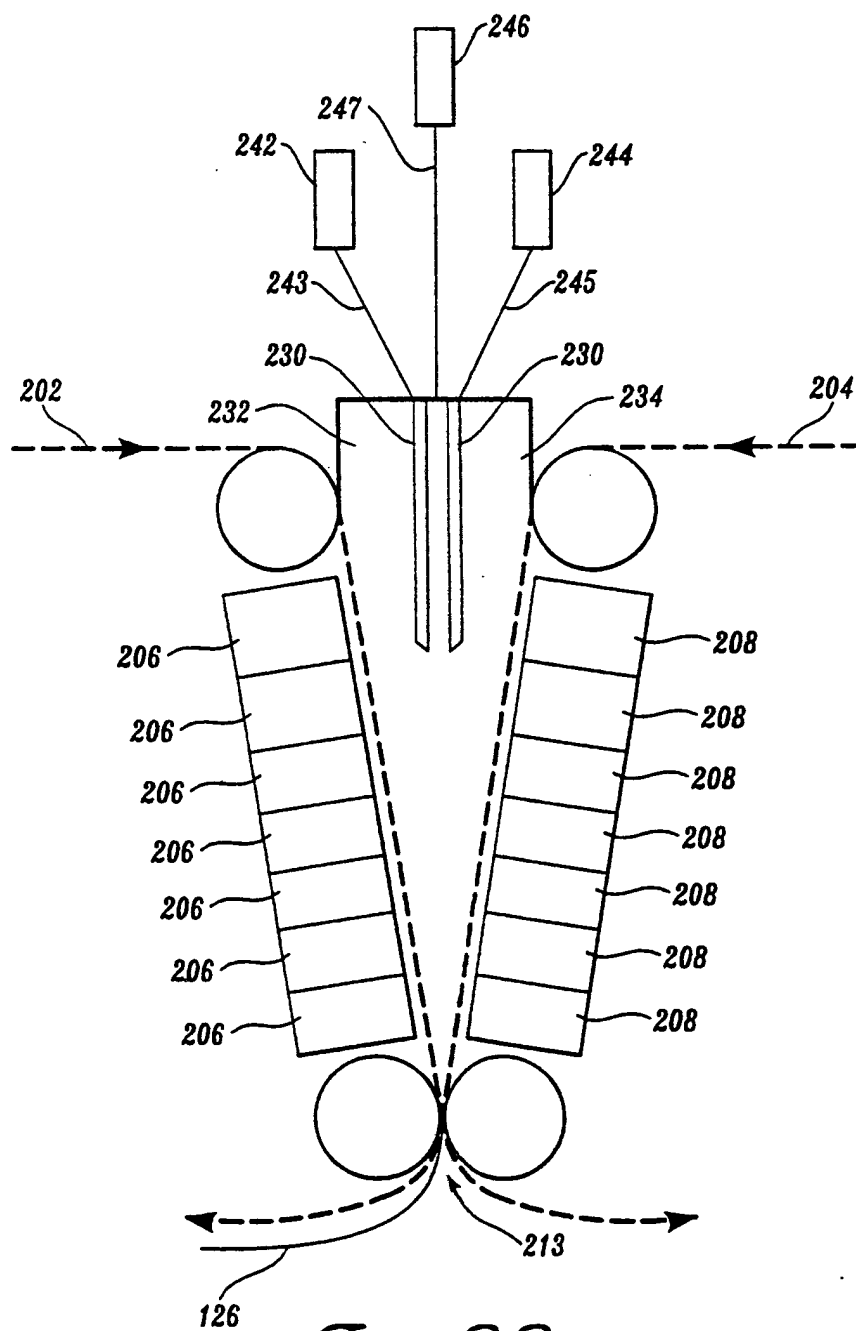
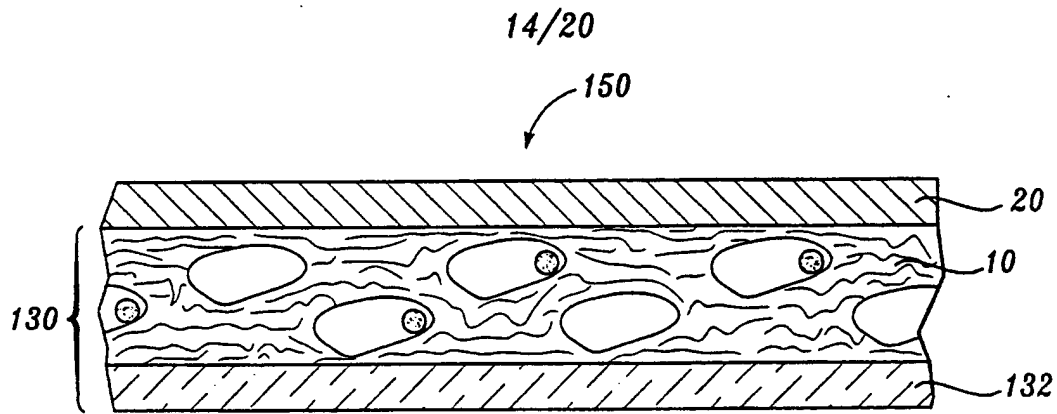


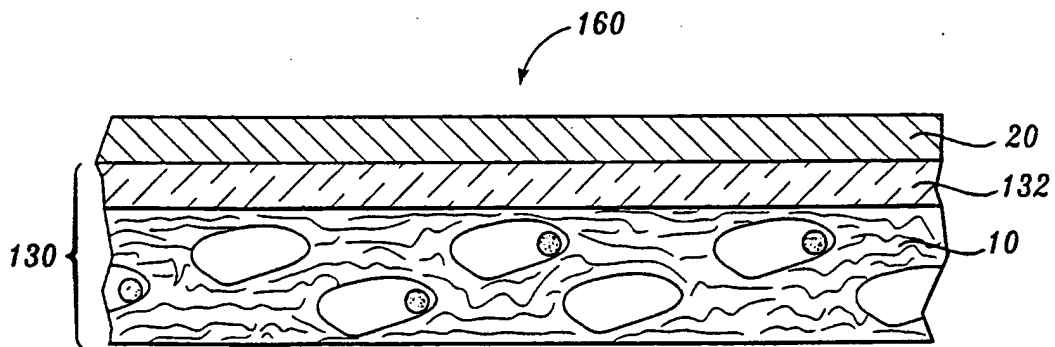
Fig. 22.

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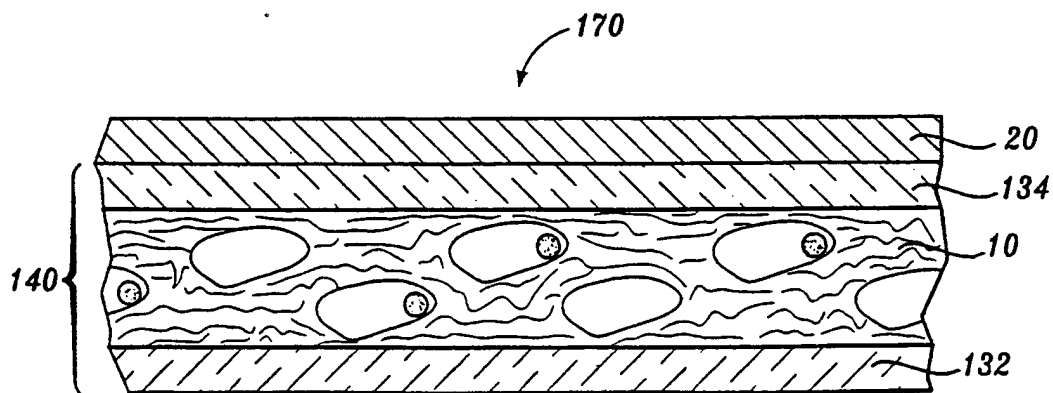
*Fig. 23.*



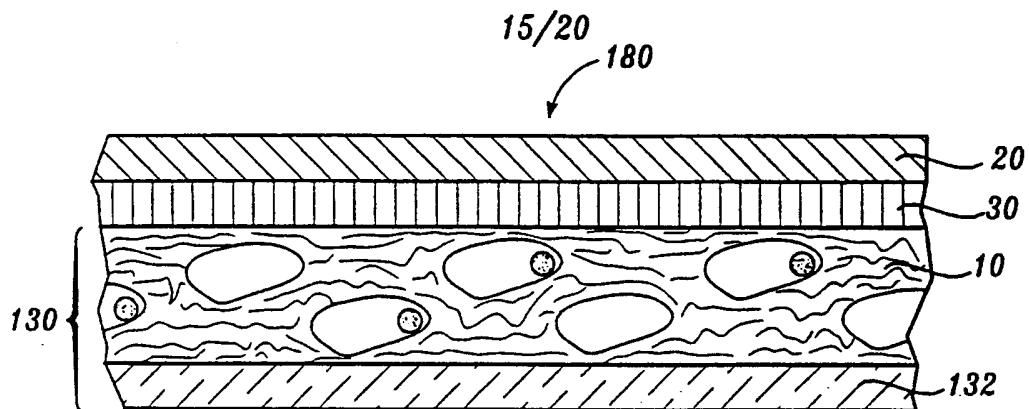
*Fig. 24A.*



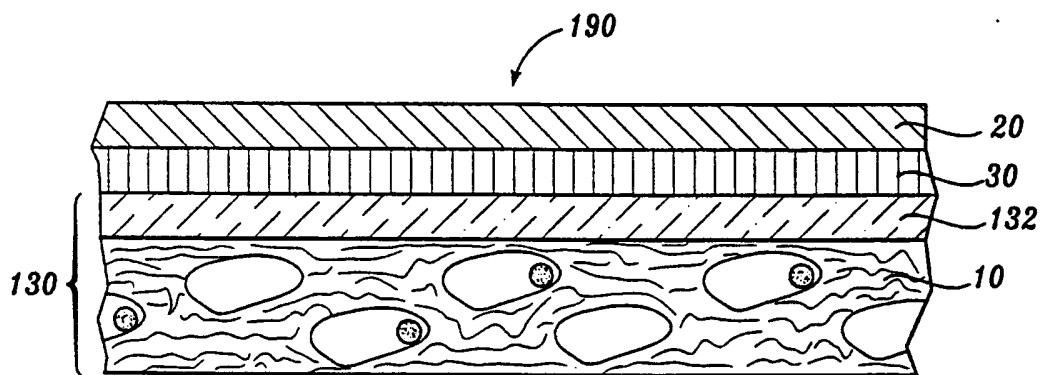
*Fig. 24B.*



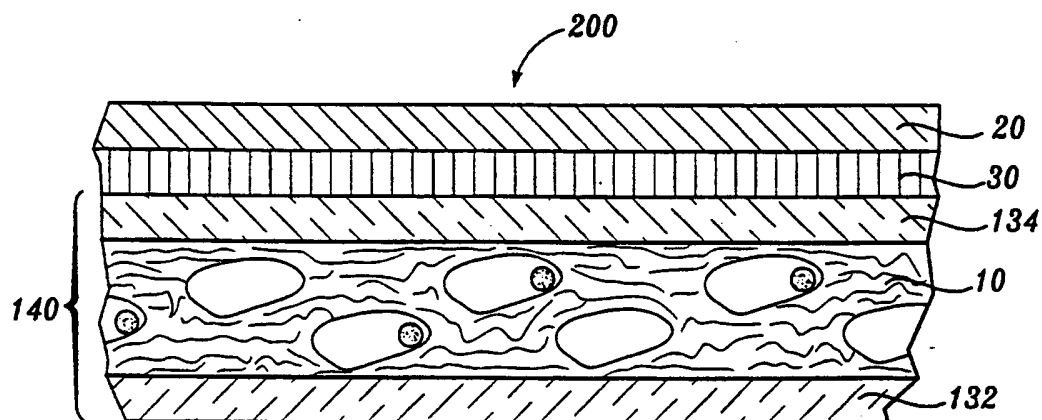
*Fig. 24C.*



*Fig. 25A.*

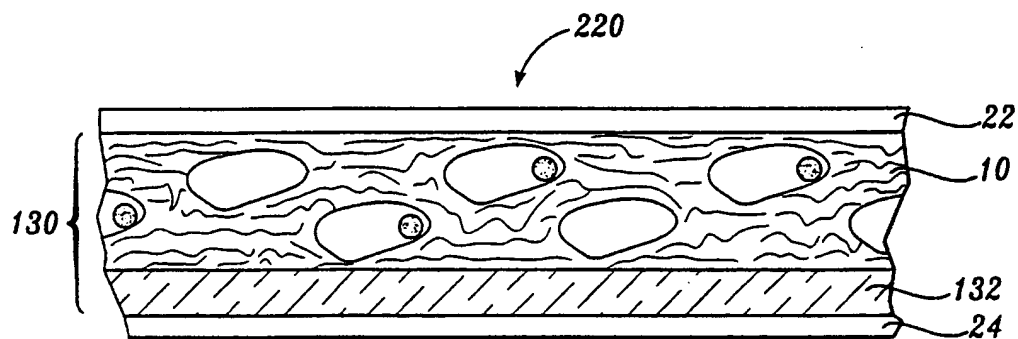


*Fig. 25B.*

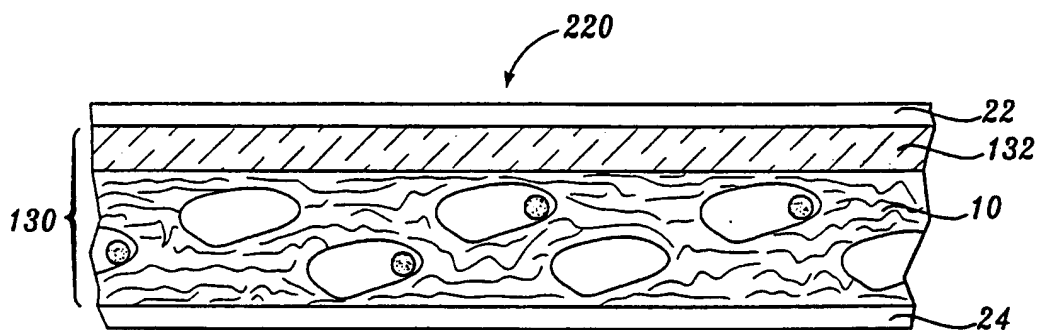


*Fig. 25C.*

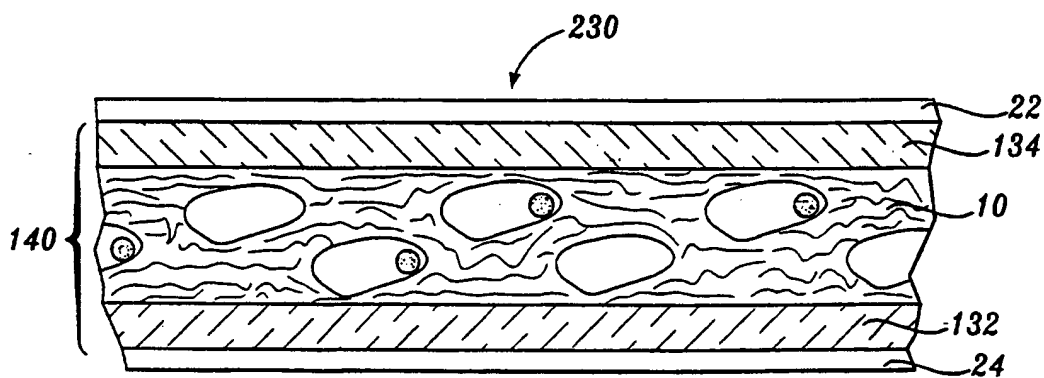
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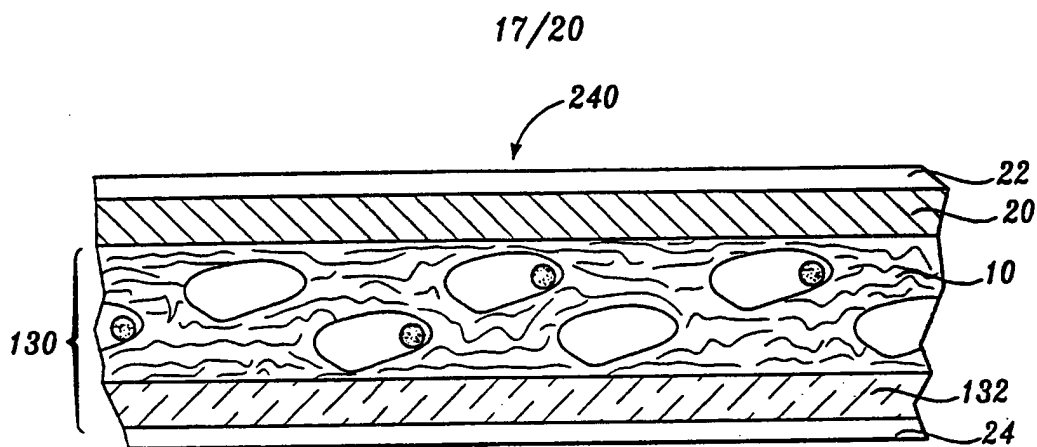
*Fig. 26A.*



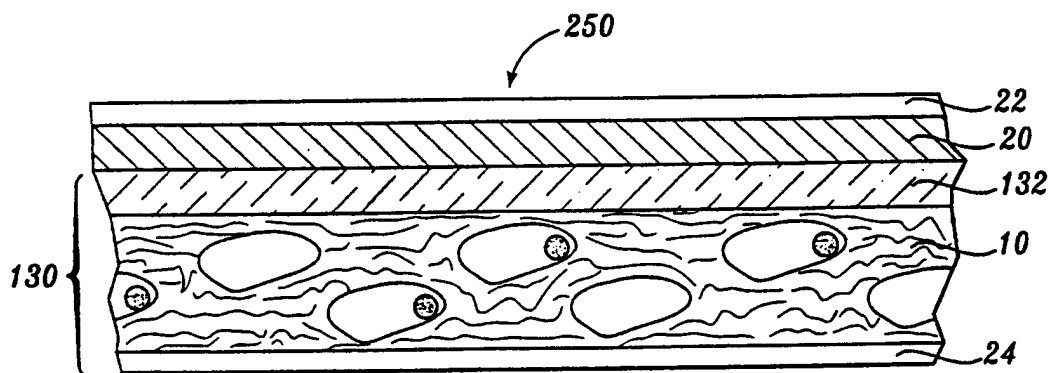
*Fig. 26B.*



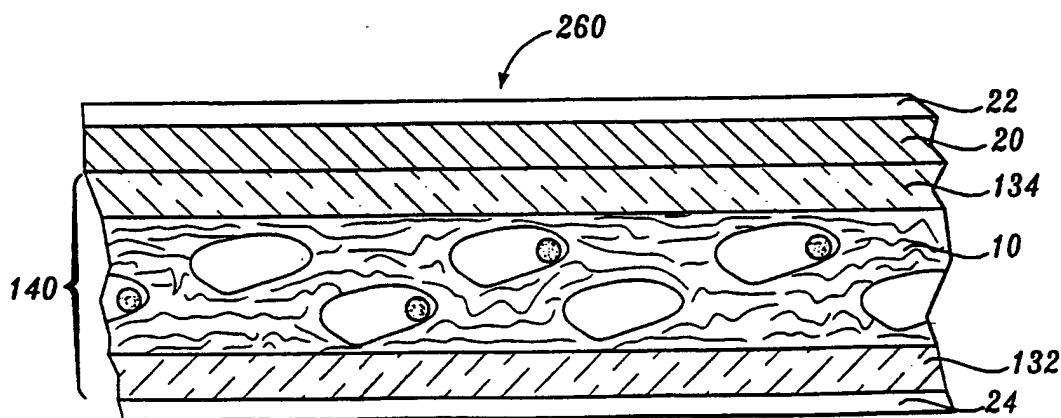
*Fig. 26C.*



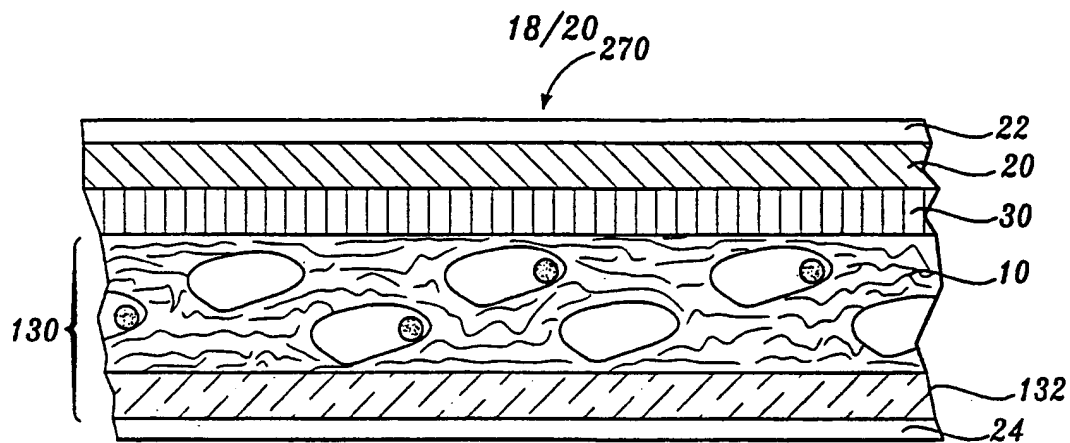
*Fig. 27A.*



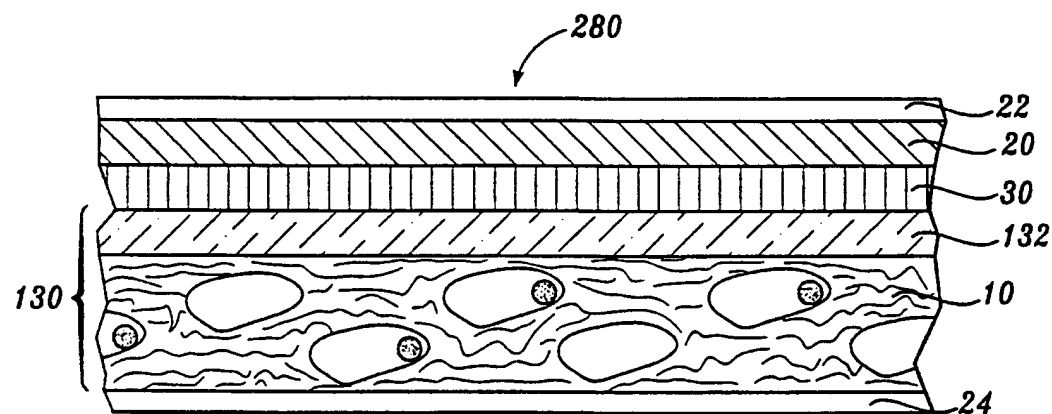
*Fig. 27B.*



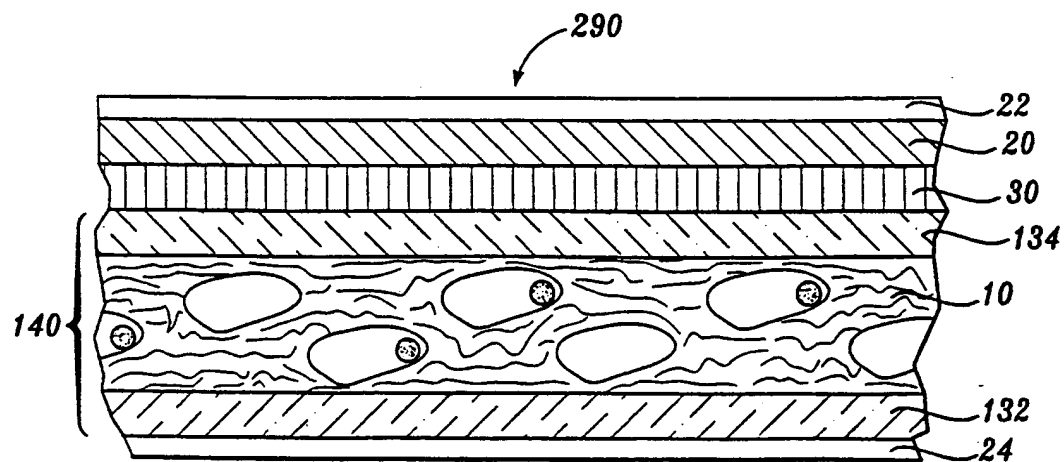
*Fig. 27C.*



*Fig. 28A.*



*Fig. 28B.*



*Fig. 28C.*

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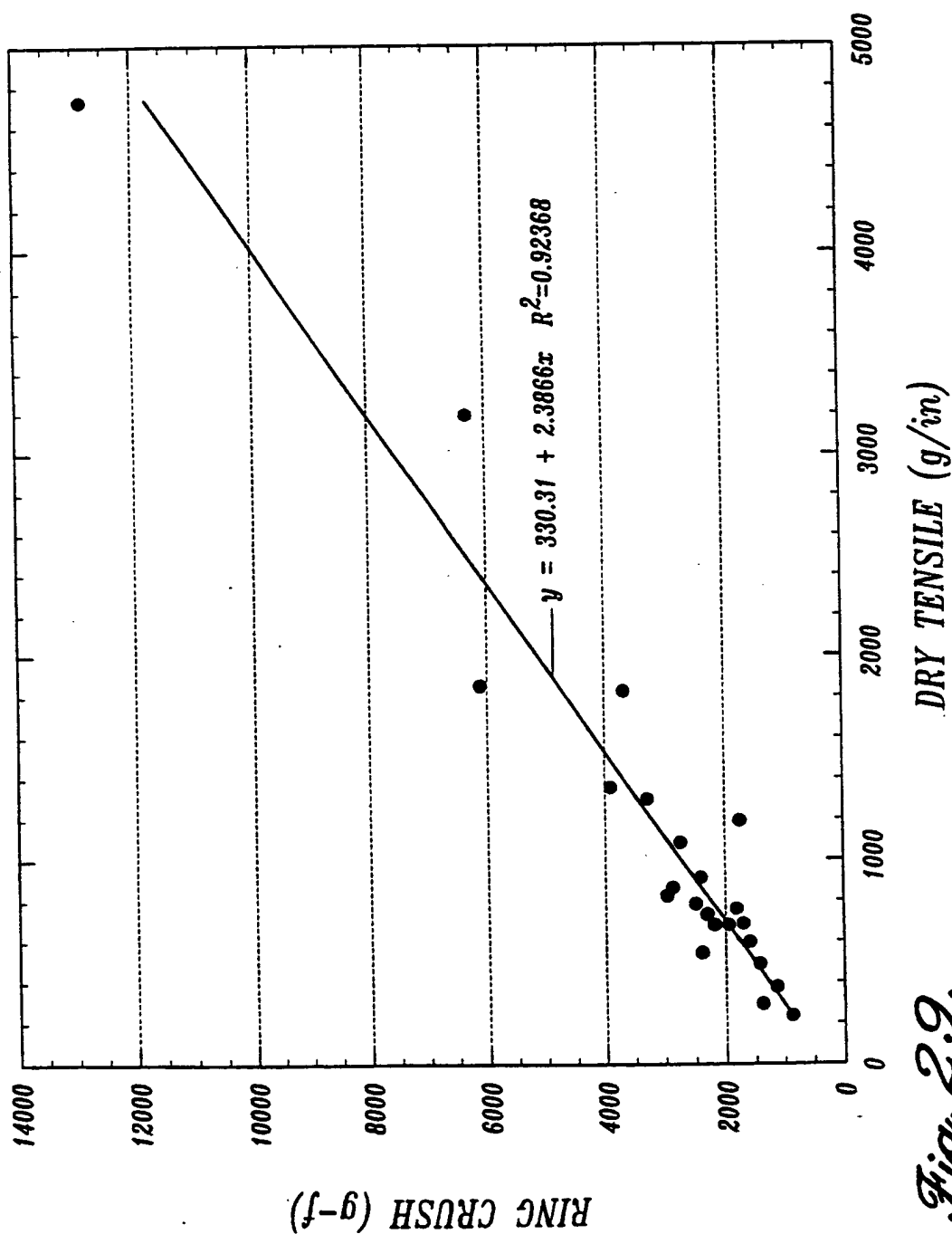


Fig. 29.



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